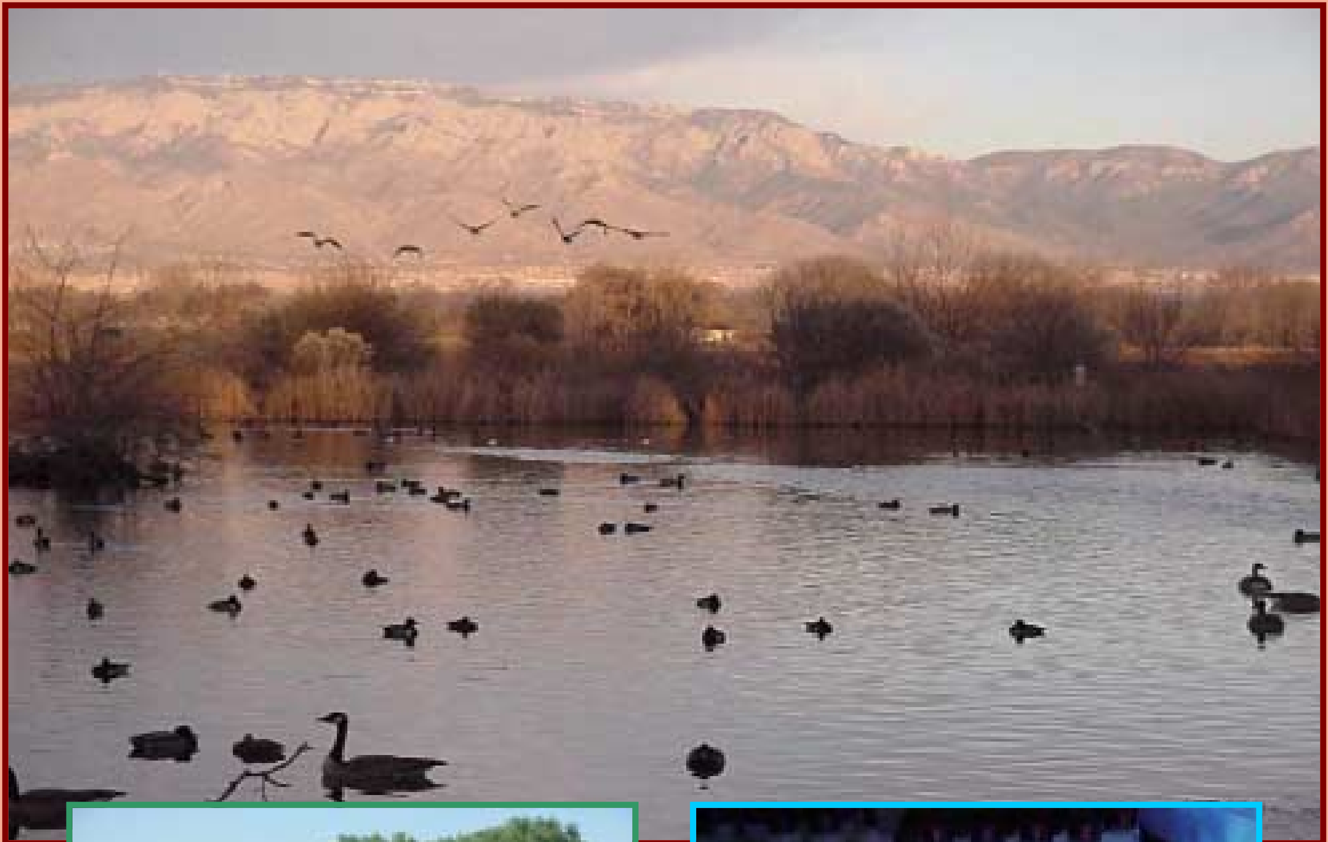
Public Health Study and Assessment of Middle Rio Grande and Albuquerque's Reclaimed Water

August 2000

Waterfowl on the Rio Grande



Livestock along Atrisco Riverside Drain

Testing for *Escherichia coli*

Public Health Study and Assessment of Middle Rio Grande and Albuquerque's Reclaimed Water

Prepared for:

Public Works Department
City of Albuquerque Wastewater Utility Division
Albuquerque, New Mexico

by:

Camp Dresser & McKee Inc
Albuquerque, New Mexico

in association with:

RhizoTech
Albuquerque, New Mexico

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WASTEWATER

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Author Profiles

Janet Yagoda Shagam, Ph.D., is a microbiologist with more than 25 years of experience teaching college-level biology, medical and environmental microbiology and chemistry. In addition, she is actively engaged in field and laboratory-based microbiology research and medical photography. Dr. Yagoda Shagam has written numerous professional articles, produced case studies for BioQuest, given presentations to various clinical, community, national and international professional organizations, serves on several editorial boards, and is currently writing a microbiology textbook for college students. Dr. Yagoda Shagam is the Southwest Regional Director for the American Medical Writer's Association and is the owner of RhizoTech.

Ronald French, Biologist, a senior environmental scientist with Camp Dresser & McKee Inc., (CDM) has spent the last 15 years working with water quality issues around the United States. Mr. French has been working on projects for many years in New Mexico which include a major water quality model development for the Rio Grande, toxicity issues associated with wastewater plant discharges, and conducting use attainability analysis on the Santa Fe River. Mr. French is one of the country's leading experts in ecological science relating to water quality. Along with other projects throughout the United States, Mr. French is currently assisting the City of Albuquerque with evaluating the microbiological water quality in the middle Rio Grande.

Robert Hogrefe, Civil Engineer, is a New Mexico native presently employed with the City of Albuquerque's Public Works Department as the manager of the Industrial Wastewater Pretreatment Program. The Pretreatment Program is responsible for regulating the industries that discharge into the City's sewer system under United States Environmental Protection Agency (EPA) regulations and City ordinances. National Pollutant Discharge Elimination System (NPDES) compliance issues surrounding stream water quality standards are also part of the City's program work. Mr. Hogrefe received his BS in Civil Engineering from the University of New Mexico and his MS in Environmental Engineering from the University of Texas at Austin. He also spent several years in Central America as a Peace Corps volunteer in water and sanitation programs, and has served as a consultant to the United States Agency for International Development to evaluate and assist similar environmental programs in Latin America.

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Glossary of Terms and Acronyms

Aerobic bacteria – Bacteria that use oxygen for the metabolism of nutrients

Anaerobic bacteria – Bacteria that do not use oxygen for the metabolism of nutrients

ASM – American Society for Microbiology

Bacteria – A small (1-10 microns) single-celled organism that does not have a nucleus

BMP – Best management practices

Bosque – Local term for the wooded riparian area that borders the Rio Grande

CDC - Centers for Disease Control

CDM – Camp Dresser & McKee, Inc.

CFU – Colony Forming Unit

City – Albuquerque

Commercial property – A property where some aspect of business is conducted

Composite sample – A sample that is made of several smaller samples to represent a larger area

Contaminated – Contain compounds or organisms that are not normally part of that substance

CWA – Clean Water Act

Discharge – The treated or untreated waste stream that emerges from a facility

Effluent – The treated or untreated waste stream that emerges from a facility

Emergent - In the context of emergent diseases and emergent pathogens – due to social and or environmental changes, microbes that were not encountered in the community are now present and can infect people, plants, and wild or domestic animals

EPA – United States Environmental Protection Agency

Epidemiology – The study of the incidence and prevalence of disease in populations

Fecal – Describes the origin of digested materials that emerge from the intestines

Fecal coliform – Facultatively anaerobic, Gram-negative, rod-shaped bacterium capable of fermenting lactose at 44.5 degrees Celsius, originating from the intestines

Fecal streptococci – Gram positive, sphere-shaped bacteria that give a positive reaction with Lancefield's Group D antisera. Fecal streptococci are associated with the feces of warm-blooded animals.

Feces – The matter discharged from the bowel consisting of undigested food, mucus, bacteria, and water

Frequency of disease – number of cases per 100,000 people

Gage – A location where measurements are made

GIS – Geographic Information Systems

Groundwater – Water that has saturated and accumulated in the ground

HAV – Hepatitis A virus

Impervious - Not porous, doesn't allow for the passage of water

Indicator organism – An organism, the presence or absence of which indicates certain conditions.

LUSTs – Leaking Underground Storage Tanks

LT – Lauryl tryptose

Microbe – Includes bacteria, viruses, and protozoan parasites

Microbial burden – The number or quantity of bacteria

MMWR – Morbidity and Mortality Weekly Report

MPN – Most Probable Number

Middle Rio Grande – Area that extends from Cochiti Dam to San Acacia, New Mexico

MUG – 4-methylumbelliferyl-β-d-glucuronic acid

Neutral – Having a pH of 7, neither acidic or alkaline

NMED – New Mexico Environment Department

Nonpoint source - Does not have a specific point of origin, runoff from parking lots or feedlots

NPDES – National Pollutant Discharge Elimination System

Oral – Referring to the mouth

Oral transmission – Transmission of disease-causing agents through the ingestion of food or water

Parasite – An organism that derives its nutrients from a living host

Pathogen – An organism that produces disease in a host

pH – A measure of acidity or alkalinity

Point source – Has a specific source of origin - a drain or an outlet

Pollutant – A natural or synthetic substance that contaminates air, food, or water

POTW – Publicly Owned Treatment Works

Presumptive positive – Based on available results, appears to be positive

Protozoan – Small unicellular microbes that, unlike bacteria, have a nucleus

Pueblo – A Native American community and its governing body

Reportable disease – Also called notifiable diseases, that due either to their severity or potential to harm the public's health must be reported to state health organizations.

Residential property – A property where people live

RFP – Request for Proposal

RGSM – Rio Grande silvery minnow

Riparian – The stripe of woodlands that grows along the borders of natural watercourses

Runoff – The rain that is not absorbed and runs of the surface

Seepage - Ground water that moves through a broad expanse of soil

Septage – Seepage that originates from a septic tank

Stormwater – The water that results directly from rain fall

Surface water – Lakes, ponds, rivers, streams, seas, and oceans – water that is on the Earth's surface

SUWCO – Sewer Use and Wastewater Control Ordinance

SWRP - Southside Water Reclamation Plant, the wastewater treatment facility

Total coliforms – Gram-negative, rod-shaped bacteria capable of fermenting lactose at 35 degrees Celsius. Includes an assortment of gut-derived bacteria as well as bacteria commonly associated with water and soil.

TMDL – Total Maximum Daily Load

Urine – The water and dissolved substances excreted by the kidney

USDA – United States Department of Agriculture

USGS – United States Geologic Survey

Virus – A very small (0.05 to 0.1 microns) infectious agent consisting of coat protein and nucleic acid, can not grow or replicate unless it has infected a host cell

Waste – In the context of animal waste refers to urine and feces, or urine and fecal contaminated materials

Waste stream – What is not kept or used by a business or residence

Waterborne disease – A disease where the pathogenic agent lives in and / or is transmitted through ingestion or contact with water

Executive Summary

Executive Summary

This report presents a benchmark study that for the first time places an in depth focus on the microbial water quality and associated public health aspects for the middle Rio Grande in the Albuquerque area. The study area included Sandoval, Bernalillo, and Valencia counties covering approximately 40 miles of the middle Rio Grande. This report summarizes a two-year effort, 1999 – 2000, which included bi-monthly river sampling, analyses, field research, and public health investigations. The study was performed by a team that included Dr. Janet Yagoda Shagam, Microbiologist, as the primary researcher, assisted by Ronald French, Aquatic Biologist, CDM Inc., and Robert Hogrefe, Environment Engineer, Albuquerque Public Works Department.

Primary Motivation for this Study

The Rio Grande, as it flows through the middle valley in New Mexico, is like many western rivers that are heavily influenced by managed river flow controls, water rights obligations, seasonal snowpack, stormwater runoff, agricultural and irrigation practices, rural and urban uses, and point and non-point pollution. The New Mexico Environment Department (NMED), in preparing for their court-mandated Total Maximum Daily Load (TMDL) determinations for the middle Rio Grande, has stated that the middle Rio Grande is impaired by high concentrations of "chlorine and pathogens". The implications from the eventual final TMDL determinations and allocations, if any, are unknown at present but did serve as the primary motivation for this study to look at the "pathogen" aspects of the middle Rio Grande and the City of Albuquerque's reclaimed water discharge from the Southside Water Reclamation Plant (SWRP).

Public Health Emphasis

This is the first study in many years to go beyond merely testing for bacterial indicator organisms such as fecal coliform and to focus on waterborne pathogens of public health significance. In addition to microbial assessment of indicator organisms and pathogens, historical and recent incidents of reportable waterborne diseases were assessed using data provided by state and national agencies. The frequency per 100,000 people, of certain potentially waterborne diseases was calculated and compared to incidents of disease at the county, state, regional, and national levels.

This study used modern refinements to isolate pathogens of concern as well as traditional indicator type bacteria that are typically reported. The traditional fecal coliform indicator bacteria as found in most NPDES discharge permits in New Mexico were tested as well as the newest EPA recommended *Escherichia coli* bacteria. *E. coli* is considered by many to be a better choice for an indicator of potentially human origin pollution. EPA may require that all municipal permits change to *E. coli* monitoring in the future.

Recent News

Recently (July 2000) the news media reported on bacterial (fecal coliform) permit exceedences stemming from problems occurring at the City of Rio Rancho (located upstream of the City of Albuquerque in the middle Rio Grande area) water reclamation facilities (Albuquerque Journal, July 2000). Interestingly, the problems that occurred brought to light high bacterial (fecal coliform) readings in the river even upstream and not influenced by the Rio Rancho discharges. This report further documents the widespread distribution of microbial populations in the middle Rio Grande. However, an important element to this water quality issue, as pointed out by state and federal regulators, is that municipal water reclamation plant discharges are held to a higher standard (i.e. lower allowed limits) than the allowable ambient river standards for indicator bacteria. This is a point not well understood by the public, especially when news of municipal discharge permit exceedences are publicized.

City of Albuquerque's Limits

The City of Albuquerque reclaimed water discharge, for example, is held to a maximum daily fecal coliform limit of 200 colony forming units (CFUs)/100 ml, which translates to only a single sample of a few ounces of water taken from a daily discharge quantity of some 55 million gallons a day. The City's limit is ten times more rigorous than the river standard of 2000 CFUs/100 ml for a single sample. These numbers are important to keep in mind when evaluating field and laboratory data presented in this report.

Public Understanding Goal

Over the years, the City has received periodic public comment and news coverage concerning the City's water discharges both of stormwater origin (which is not mixed with domestic wastewater) and of the reclaimed domestic wastewater from the SWRP. Previous reports have demonstrated that both the media and the public do not understand the microbial and public health significance of surface water microbiology, the use of indicator organisms nor the relative human health risk potentials involved.

This study will help to increase the public and media's understanding of the surface water microbial conditions of the middle Rio Grande/Albuquerque area, the relative public health risks, and the many and varied sources of microbial contributions to the river. Of particular importance to the City is the achievement of a better public understanding of the City's EPA imposed high standards necessary to achieve treated reclaimed water in comparison to the Rio Grande itself.

Representative Sampling

One of the City's objectives for this study is to bring to light the issue of representative sampling for microbial quality. The City's reclaimed water must meet a permit limit 10 times lower than the ambient river standard in a single few ounce (or one-third cup) samples taken from a total daily reclaimed water volume of some 55 million gallons. The City has never considered this sampling requirement to be a representative measure of microbial water quality in the reclaimed water discharge. EPA has suggested and the City agrees that a better approach would be to conduct monitoring on an averaging basis as opposed to a single sample, especially if held to the lower limit. An averaging method would validate multiple sampling of the large volume of discharge to provide a truer representation of microbial quality. This would also be consistent with many policies and permits across the country.

Intentional Raw River Water Ingestion

This study also provides an important perspective on the practice of intentional ingestion of raw river water from the middle Rio Grande. The State of New Mexico has never adopted any kind of water quality standard or use for the Rio Grande as a raw (untreated) potable drinking water source. The fact that two Indian pueblos in the middle Rio Grande area, the Sandia and the Isleta Pueblos, have adopted ceremonial intentional water ingestion as a use for the Rio Grande is, from a public health perspective, not recommended given the documented wide range of microbial species and natural and human influenced contamination sources into the river. The Pueblos would be better served by water quality standards based on what are safe, realistic, and attainable quality levels that presume conventional water treatments are applied to raw water before it becomes potable/drinkable.

Findings From This Study

- The highest concentrations of microbial populations were found starting at the far southern end of the sample locations i.e. generally at and below the Isleta Pueblo boundaries.

- *E. coli* could be used as a better indicator organism of potentially human origin pollution to replace fecal coliform, consistent with EPA recommendations.

- Rio Grande microbial water quality appears to be adversely affected by both point and non-point sources both upstream and downstream of the City's wastewater treatment plant. Examples follow.

    a) Significant numbers of wild birds use the Rio Grande as a major flyway as do many varieties of resident animal populations, together they adversely affect the microbial quality of the river all year.

    b) Livestock rearing and livestock operations produce contaminated runoff, which can and do enter the canals and river.

    c) Land use and land management practices contribute contaminated runoff and seepage into the canals and river.

- Microbial water quality upstream from the SWRP is less impaired than sites downstream from the SWRP, for mostly unknown reasons.

- Microbial water quality upstream and downstream of the City's discharge is significantly more impaired than discharges coming from the SWRP and Outflow channel.

- Water being discharged to the Rio Grande from riverside drains and canals is of lower quality than water being discharged from the SWRP.

- Groundwater influences may be significantly contributing to river and canal microbial populations, and deserve further research. Factors affecting groundwater (septic tanks, livestock practices, leaking underground tanks) appear to deserve equal attention as for surface non-point sources of pollution.

- Pathogen impairment of water quality in the middle Rio Grande will likely continue to be a problem until both groundwater and non-point sources of pollution are addressed. What is difficult to estimate, is the degree to which long lasting microbial improvement in water quality is achievable given the diversity of both man-made and natural sources of pollution.

Section One

Section 1
Introduction and Background

1.1 Introduction

Section 303(d) of the Clean Water Act (CWA) allows states to identify impaired or threatened waters and submit the lists to the EPA and state regulatory agencies. The Section 303(d) list is a prioritized list of waters not meeting water quality standards, and states must take necessary action to remove waterbodies from this list. The middle Rio Grande, as it flows through Albuquerque is like many western rivers that are influenced by stormwater, municipal wastewater, industrial discharges, agriculture, and non-point sources. According to the 303(d) list, the middle Rio Grande is impaired by high concentrations of chlorine and pathogens (fecal coliform). A TMDL is being developed for the river by the NMED, in conjunction with EPA Region VI to address the potential sources of impairment.

The City has taken aggressive steps to reduce the level of total ammonia, chlorine, and pathogens from the City's SWRP discharge. The City has implemented dechlorination of the effluent to remove chlorine and has built nitrification reduction facilities to reduce total ammonia in the final effluent. The City is also meeting its disinfection requirements for bacteria, and actually had to modify the new nitrification system to allow for trace additions of ammonia in the process to ensure complete disinfection. Currently, bacteria levels as measured by fecal coliforms are reduced from one million to one-hundred million CFUs in the influent to less than 100 CFUs in the effluent.

Over the years, cities in the middle Rio Grande region have received public comment concerning the effects of discharges, both of stormwater origin and the reclaimed effluent from publicly owned treatment works (POTWs) (Photos 1-1 and 1-2), on Rio Grande water quality. In particular local media have published reports that indicate that the cities, on occasion, have been out of compliance with respect to discharge of fecal coliforms to the river. By contrast, what is not understood is that the municipal microbial limits are as much as ten times more stringent than the river standard.

This situation demonstrates that both the media and the public do not fully understand the nature of microbial reporting, the associated public health significance of surface water microbiology, and the relative risks for potentially waterborne disease. However, many people throughout the Unites States have become wary of community water supplies as a result of the barrage of recent heavily publicized reports of waterborne illnesses.

A recent survey of the public's perception of risk and disease reveals a substantial gap in understanding (USDHHS, CDCb, 2000). The Centers for Disease Control (CDC), through a national telephone survey of over 1,200 registered voters, found that over half of the respondents could not define “public health.” The survey also revealed that the majority of respondents believe that contaminated water and food have the greatest impact on their personal health and the incidence of disease in the community.

While the results of this survey should not detract from programs that protect the health of citizens and our environment, they do demonstrate that both the media and the public do not appreciate the role of human activity on the transmission of waterborne infectious agents through the community. Because health-related information is often disseminated in a form that is not easily understood, the public often has an inappropriate perception of risk.

1.2 Purpose of Study

For many years the City’s Wastewater Division has been working on long-range wastewater plans. These efforts are needed, as the community grows and become more industrialized, to protect surface water and groundwater supplies from contamination.

The purpose of this study is to provide a detailed microbial assessment of Rio Grande water with a focus on the influences of the City’s SWRP on river water quality. The goal of the study is to describe and compare pathogens that originate from a variety of sources, and investigate non-point sources (agricultural runoff, stormwater, etc.) that can significantly contribute to a waterbodys’ impairment. To determine the microbial impacts to the middle Rio Grande, the following elements are presented:

- A year-long microbial assessment of Rio Grande water at multiple sites upstream and downstream from the SWRP discharge

- A year-long microbial assessment of SWRP discharge water

- Ground and aerial investigations for potential sources of microbial contamination due to run-off, septage, seepage, and the flow of stormwater over impervious surfaces

- A field-based assessment to identify potential sources of microbial contributions resulting from agricultural runoff, bird fly-through zones, wild animals, and industrial and residential sources

- A historical and current year assessment of reportable potentially waterborne diseases and the causal relationship between SWRP treated effluent and upstream / downstream Rio Grande water quality.

- Summary of results in the context of public health and public understanding of the microbiology of wastewater treatment, river microbiology, and waterborne disease.

1.3 Background

1.3.1 The Rio Grande

The Rio Grande, New Mexico's major waterway, runs nearly 2,000 miles from Colorado to the Gulf of New Mexico. The river, running the full length of the state of New Mexico, passes through high mountainous regions, valleys, and plains (USGSa).

The river is a complex and fragile ecosystem that has created many unique environments along its perimeter. Riparian environments, where land and water meet, support diverse and complex populations of plants and animals. In addition to being environmentally distinct from ecosystems just a few hundred feet away from the river's banks, the riparian strip (locally known as the "bosque") acts as a biological filter and purifies chemical and microbial run-off and seepage before it enters the river. When riparian environments are lost to over-grazing and urban development, water quality can quickly deteriorate.

The middle Rio Grande region extends from Cochiti Dam downstream to San Acacia- a small farming community about 50 miles south of Albuquerque. This stretch of the river includes high desert range and farmland, extensive flood plains, high-density urban and industrial areas, and numerous state and federal nature preserves. Nearly 700,000 people, or close to 50 percent of the population of the entire state of New Mexico, live near or along this 100-mile stretch of the Rio Grande (USCB, 1999).

The Rio Grande has become increasingly influenced by urbanization, agriculture, industry, and strategically placed dams (Photo 1-3). And now, due to the cumulative effects of diversions, consumption, flood control, irrigation, and pollution, the Rio Grande is ranked as the 7th most endangered river in the United States (Albuquerque Journal, January 8, 2000).

There are many reasons how and why the Rio Grande achieved this status. While some of the causes for river deterioration are directly related to the diversion of river water to meet agricultural and community needs, many others result from chronically low rainfall, mountain snowpack, over-grazing, and urban and agricultural development. However, for the purposes of this study, the emphasis will be on the environmental and community based issues that affect point and non-point sources of microbial discharge to the Rio Grande and potential health impacts.

1.3.2 Point and Non-Point Sources of Microbial Contamination

Point sources involve the discharge of substances from defined entities such as industry, wastewater treatment facilities, and power plants. Point source contamination is regulated through the NPDES which controls the concentration of specific effluent constituents.

Non-point sources of pollution, often scattered over broad areas, are difficult to define and control. Non-point sources of pollution include agricultural runoff, stormwater, seepage from septic tanks, and leaking underground storage tanks (LUSTs). Non-point source regulations emphasize the implementation of best management practices (BMP) to lessen the effect of contaminated runoff on environmental quality.

BMPs used to limit non-point contamination from runoff and stormwater often involve the establishment and maintenance of vegetation and riparian woodlands to lessen erosion and to increase filtration of contaminants before they reach surface or ground water. In addition to the establishment and maintenance of vegetation, runoff from farms and feedlots is prevented from washing into waterways using BMP, such as containment and filtering techniques.

Certain industries are required to obtain storm water permits. Runoff from these industries must be contained unless it is shown that it does not contain dangerous amounts of chemical or microbial pollutants. Other strategies used to limit the impact of non-point sources on surface and groundwater include zoning and agricultural regulations to lessen the amount of contaminated seepage, septage, and runoff entering surface water.

There are many potential sources of microbial pollution along the Rio Grande. Point sources include waste treatment facilities that may discharge potentially pathogenic microbes and microbe-supporting nutrients in their waste effluent. However, because these generators must conform to rigorously imposed state and federal discharge regulations and standards, these sources of pollution are usually no longer a major cause of surface water contamination.

Non-point sources of discharge such as urban (Photo 1-4) and agricultural run-off, seepage and septage, contributions from illegal dumping, and wild animals and birds are suspected to contribute the most pollution to the Rio Grande. These sources of discharge are not only difficult to locate and identify, but due to their very nature are difficult to control and regulate. This study examines these factors in depth for their microbial pollution potential.

1.3.3 Impact of Human Activity on the Rio Grande

In New Mexico, the Rio Grande is heavily influenced by human activity. However, human use of the river has ancient origins. Indigenous people as well as 14th and 15th century European immigrants developed communities by the river's banks and used Rio Grande water to meet their daily needs, irrigate fields, and provide water for livestock.

According to the State of New Mexico's report on *Water Quality and Water Pollution Control in New Mexico* (State of New Mexico, 1996), agricultural activities, municipal point sources, storm sewers and runoff are the biggest sources of Rio Grande contamination. The combined effects of silt, chemical contamination, and microbial contamination have compromised a nearly 40-mile stretch of the middle Rio Grande between the Jemez River and Isleta Pueblo. State of New Mexico designated uses such as secondary contact, limited warm water fishery, irrigation, and wildlife habitat are sometimes impaired or only partially supported. Indian Pueblo water quality standards for ceremonial intentional ingestion of raw river water have been adopted. Questions have arisen as to the attainability of this ceremonial water use under the applicable definition of the CWA.

1.3.4 Naturally Occurring Microbes in the Environment

Because of their ability to decompose and chemically alter organic and inorganic molecules and compounds, the role of microbes on this planet is to recycle nutrients. Without bacteria, viruses, and fungi, our planet could not support life. Microbe-free surface water would not be able to support the growth of plants, fish, and other animals. Nutrients would be locked up in large organic molecules and oxygen would not be replenished through photosynthesis.

However, just like other communal relationships, detrimental members of the community must not be allowed to thrive at the expense of other productive community members. To prevent surface waters from becoming overwhelmed by potentially pathogenic organisms, care must be taken to protect the environment and limit conditions that encourage their proliferation.

1.3.5 Potentially Waterborne Pathogenic Bacteria

Certain waterborne bacteria may cause disease when they are ingested in contaminated water, inhaled in aerosols, or introduced into the body through a break in the skin. The following are examples of some commonly occurring potentially waterborne pathogens in the United States. *Campylobacter jejuni* is thought to be the causal agent of 5-11% of all cases of diarrhea. Common-source outbreaks of *Campylobacter* are often associated with contaminated chicken, unpasteurized milk, or the consumption of unchlorinated water. Although the specific type of *Campylobacter* that infects humans is unable to grow in water, it retains its viability when in cold or chilled water. *C. jejuni* is often found in aquatic environments that are affected by sewage, birds, and other wild animals. Annually there are at least 2 million cases of *Campylobacter* diarrhea, a situation that affects nearly 1% of the population of the Unites States.

The *Vibrio cholerae* bacterium, shed in the fecal matter of infected individuals, can survive for long periods away from its human host. Although *V. cholerae* is not fresh-water hardy, several outbreaks of cholera have been linked to the consumption of untreated or under-treated drinking water, and to bottled spring water. Though in industrialized parts of the world cholera is rare, there is concern that cholera could become a problem if the chlorination of drinking water is under-utilized.

Leptospirosis is a bacterial infection that may result when abraded skin or mucus membranes are exposed to water contaminated with the urine of wild and domestic animals. Rats, pigs, cows, raccoons, deer, and squirrels are often the reservoir for *Leptospirosis interrogans*. Infection with this bacterium is a recreational hazard for people who swim, camp, fish, or boat in contaminated waters. Because of low incidence, this disease was removed from the CDC list of reportable diseases for 1998.

Escherichia coli is a normal intestinal inhabitant of humans and other warm-blooded animals. Therefore, when *E. coli* is found in water it indicates fecal contamination that originated from humans or other animals. The presence of *E. coli* indicates a potential for other gut-derived pathogens to be present also. Many documented outbreaks of waterborne disease have been directly linked to the presence of *E. coli* in water. Often affecting hundreds and even thousands of people, these outbreaks are usually associated with cross-contamination of drinking water with sewage, under-chlorination of drinking water supplies, or contamination of recreational waters with human or animal wastes. EPA has recommended that *E. coli* be substituted for fecal coliform as a better indicator organism.

Ingestion of *Shigella* in contaminated water or food produces acute gastroenteritis and dysentery. Illness can range from mild self-limiting diarrhea to severe toxicity and kidney failure. Infected humans are the only significant reservoir for *Shigella*, and transmission occurs through contact with patients and carriers of the disease or by ingestion of contaminated food or water. Shigellosis occurs worldwide but is most common in areas where sewage treatment and personal hygiene are inadequate.

Shigellae are sensitive to chlorination, are not competitive with other microbes, and are not highly persistent in river water. Waterborne outbreaks of shigellosis are most commonly associated with fecal contamination of non-chlorinated private and community water supplies. Under-treated water and cross-contamination between wastewater and potable water are the most frequent sources for outbreaks linked to drinking water supplies. Outbreaks have also been associated with recreational waters as well as to the consumption of raw and improperly cooked fish and shellfish harvested from contaminated waters.

Like *E. coli* and *Shigella*, *Salmonella* is one of many enteric bacteria that contaminate water and food. There are many different varieties of *Salmonella*, many of which are pathogenic for both humans and animals. However, unlike *Shigella*, which is associated almost entirely with humans, biological reservoirs for specific *Salmonella* species also include birds, cattle, rodents, turtles, snakes, and lizards.

In 1993 a waterborne outbreak in Missouri that affected more than 650 people and resulted in 7 deaths was attributed to a water storage tower that permitted free access to birds. Outbreaks of waterborne *Salmonella* usually involve poor-quality source water, inadequate treatment, or contamination of water distributions systems. In 1996, in a similar incident in Orion Township, Michigan, birds were again implicated in contaminating a water tower. However, in this case, no incidents of illness were reported in connection with the contamination. Because the Rio Grande is a significant flyway for migratory birds, there is the potential for similar microbial contamination to occur in the river.

Fecal coliforms, a major fecal constituent, are naturally associated with the excrement of humans, livestock (Photo 1-5), and wildlife. These organisms can enter rivers though runoff from domestic sewage, livestock facilities, streets, homes, and wildlife excrement into rivers. Since these bacteria are consistently found in human and warm-blooded animals' feces, they have been used as indicators to suggest the presence of gut-derived pathogens in public waters. Some waterborne associated pathogenic diseases include gastroenteritis, dysentery, and typhoid fever.

Very few species of coliform bacteria are harmful, as some coliform bacteria are found in soil, and can grow inside water pipes and wells. Their presence and detection in surface water does not mean that the water is necessarily unsafe to use. This is a distinction typically lost in the reporting of fecal coliform counts in water bodies.

1.3.6 Potentially Waterborne Pathogenic Viruses

The enteroviruses are a diverse group of viruses that cause gastrointestinal disease when consumed in contaminated water or food. Three groups of viruses - Norwalk virus, Norwalk-like viruses, and the rotaviruses - are well-documented causes for food and waterborne gastrointestinal disease. Contaminated water is the most common source of outbreaks and may include water from municipal supplies, well-water, recreational waters, swimming pools, and water stored aboard cruise ships. It is estimated that the Norwalk and the Norwalk-like viruses are responsible for one-third of the cases of gastroenteritis in people older than two years of age.

Another group of enteroviruses are the rotaviruses. These viruses, in addition to being spread through exposure to contaminated food and water, are easily transmitted by contact with virus-contaminated hands. Once the virus has entered a community, direct contact is probably the most important means by which it moves through homes, hospitals, daycare centers, and long-term care facilities. Over 3 million cases of rotavirus gastroenteritis occur annually in the United States.

Waterborne hepatitis results when the hepatitis A virus (HAV), shed in the fecal matter of infected people, contaminates water. Humans, both the main reservoir and host for this virus, may become infected when they are exposed to HAV in contaminated or cross-contaminated food and water.

HAV is a very persistent virus, and unlike many other waterborne viruses is stable under a wide range of environmental conditions. It is stable in water up to 80 degrees Celsius and can withstand pH levels as low as 1 and as high as 10. It can be deactivated with free chlorine and ozone, but even this treatment may not be sufficient in water heavily contaminated with organic materials.

Once the disease enters a community the virus is spread through eating improperly cooked fish and shellfish harvested from HAV-contaminated waters, ingestion of contaminated fresh water or groundwater, use of contaminated water in food preparation, and cross-contamination of food and water through poor personal or kitchen hygiene habits.

Though hardly a trivial infection, often taking several weeks for recovery, this type of hepatitis is a self-limiting disease of low lethality. HAV is easily spread within households and the community at large but tends to cluster in daycare centers and other places where people live in close contact with others.

A vaccine, made from inactivated virus particles, is available, and it is recommended that school-age children, people who travel to areas where the virus is endemic or people who have a high potential for exposure be vaccinated. According to the CDC in 1998 there were 23,229 cases of HAV reported in the United States.

1.3.7 Potentially Waterborne Pathogenic Parasites

Considering the amount of media exposure devoted to *Cryptosporidium*-related topics, it is amazing to discover this protozoan was largely unknown until it was associated with an outbreak of bovine diarrhea in 1971. A few years later (1976) the first cases of human infection were reported to the CDC and in 1982 physicians noted its association with severe cases of diarrhea in immunocompromised patients. Since 1984, when the first documented waterborne illness was reported, to the highly publicized Milwaukee outbreak in 1993, the public has become more aware of this pathogen in water supplies.

One of the first reports linking *Cryptosporidium* infection to the consumption of untreated surface water occurred in New Mexico. In 1986 (July-October) 76 laboratory confirmed cases were identified. Of these cases, 58 individuals lived in Bernalillo County. However, it is important to take into consideration that several of these cases resulted when infected individuals transmitted the disease to children in a daycare center (Grabowski, 2000). As is the case with many potentially waterborne pathogens, the most likely source of exposure to *Cryptosporidium* is person-to-person contact, contaminated food, or through contacts with household pets.

Entamoeba histolytica is a single-celled parasitic protozoan that infects humans and other primates. Although other animals, particularly dogs and cats, can become infected, infective forms of the parasite are not usually shed in their fecal matter.

Transmission of this parasite is through exposure to contaminated drinking water and food, cross-contamination with dirty hands, or sexual contact. Infection sometimes lasts for years and may be accompanied by vague gastrointestinal symptoms, severe bloody diarrhea, as well as infection and invasion of other organs. Some people are unaware of their infection, while others who are immunocompromised due to medical treatment or other underlying disease processes become very ill when infected by *E. histolytica*.

Unlike *E. histolytica*, a protozoan that primarily infects humans and other primates, *Giardia lamblia* has a large host-range that includes humans, dogs, cats, beaver, and bears. *Giardia* is the pathogen most frequently identified as the cause for strictly waterborne outbreaks of giardiasis in the United States. Many of these outbreaks involved surface waters that did not receive adequate disinfection or groundwater contaminated by fecal matter (AWWA, 1999). Because the *Giardia* cysts shed in feces can remain viable for as long as 84 days in cold water, clusters of waterborne giardiasis often are more likely to occur in the mountainous areas of the United States.

Like other waterborne pathogens, *Giardia* is closely associated with oral-fecal transmission. Giardiasis is a common problem in daycare facilities and nursing homes where the staff may be involved both in preparation of food and patient personal hygiene. In the United States, between the years 1971 and 1996, there have been 28,129 reported cases of giardiasis (AWWA, 1999).

Table 1-1: Summary of Some Waterborne Diseases of Concern in the United States (EPAc)

Disease	Type of Microbe	General Symptoms
Amebiasis	Protozoan – *Entamoeba histolytica*	Abdominal pain, fatigue, diarrhea, gas, weight-loss
Campylo-bacterosis	Bacterium – *Campylobacter jejuni*	Fever, abdominal pain, diarrhea with accompanying bloody mucus
Cholera	Bacterium – *Vibrio cholerae*	Watery diarrhea, vomiting, muscle cramps
Cryptosporidiosis	Protozoan – *Cryptosporidium parvum*	Diarrhea, abdominal pain
Traveler's diarrhea	Bacterium – *E. coli*	Diarrhea
Giardiasis	Protozoan – *Giardia lamblia*	Diarrhea, abdominal pain, weight-loss
Hepatitis	Virus – hepatitis A	Fever, chills, abdominal pain. jaundice, dark urine
Leptospirosis, Weil disease, Mud fever	Bacterium – *Leptospirosis interrogans*	Fever, headache, chills, muscle pain, rash, jaundice, kidney failure
Shigellosis	Bacterium – *Shigella* species	Fever, bloody diarrhea
Salmonellosis, Typhoid fever	Bacterium – *Salmonella typhi*	Fever, headache, constipation, appetite loss, nausea, vomiting, abdominal rash
Viral Gastroenteritis	Enteroviruses – Norwalk virus, rotavirus and others	Fever, headache, gastrointestinal discomfort, vomiting, diarrhea

1.3.8 Stormwater Runoff and Seepage

Stormwater runoff in the Albuquerque area (Photo 1-6), although very noticeable during infrequent seasonal heavy storms, only constitutes 0.8% of the annual flow volume in the middle Rio Grande (Parsons 1999). The City, in conjunction with the United States Geological Survey (USGS), has regularly sampled stormwater runoff for a variety of parameters including microbial populations since 1992. The City's EPA stormwater permit has been applied for and is pending EPA action. Tests on 100% stormwater runoff have been performed in sensitive biomonitoring studies. The biomonitoring studies have proven that the stormwater runoff is completely nontoxic. This is an indication that no combination of substances is occurring to produce potentially toxic effects to aquatic organisms.

The NMED has sampled the middle Rio Grande during stormwater events at many locations. NMED's data for fecal coliform samples collected during 1999 indicated the data range listed in Table 1-2. The data collected in the Rio Grande in 1999 by NMED reflect both storm and non-storm periods. The range in the data is believed to reflect higher coliform concentrations occurring throughout the entire region during stormwater events from contributions of a variety of overland flows directly into the Rio Grande. This is not surprising as the City has collected data in previous years from watersheds upstream from urbanized areas that have contained large concentrations of fecal coliform organisms. (Meinz, 2000). Results from NMED's 1999 TMDL sampling is provided in Appendix A.

Table 1-2: Middle Rio Grande Fecal Coliform Data (NMED data, 1999)

Location	Data Range (CFU/100 ml)
Above Hwy 44 Bridge	34-400
Above Alameda Bridge	50-2400
Above I-25 Bridge	150-2100
Above Isleta Diversion	140-1800

Source: NMED-TMDL sampling, 1999, membrane filtration data only. Most Probable Number (MPN) methods showed wider ranges. Data in Appendix A.

Water, when it makes contact with the ground is either quickly absorbed into the soil, or it runs over the surface until it is deposited elsewhere. Runoff water is not absorbed if the ground lacks vegetation, is compacted, or is covered by asphalt or cement. The water that flows over these non-absorbent surfaces picks up and becomes contaminated with particulates, microbes, and water-soluble chemicals that are eventually deposited into surface water.

In 1979 Casserly and Davis demonstrated that urban stormwater runoff is responsible for more than 50% of the annual contribution to surface water pollutant loading. In addition to chemical contamination, water that flows over compacted earth, asphalt, or cement is warmed, thereby becoming a source of thermal pollution.

Water that soaks into porous ground may be held in the soil or it may percolate through the soil until it encounters an impervious layer or reaches a surface opening. Seepage is the absorbed water that flows through a broad underground area. As the water moves through the soil it may absorb naturally occurring minerals and pick-up contaminants from chemical spills, LUSTs, or septic tanks. Naturally occurring bacteria in soil serve to remediate some contamination.

1.3.9 Septage

A septic tank is a large, underground, watertight box used to collect and treat the raw sewage and other organic materials contained in domestic wastewater. Bacteria in the tank degrade the organic materials, thereby partially cleaning the water which is eventually discharged into the soil. Non-degradable materials accumulate in the tank until it becomes necessary to pump and remove the sludge for further treatment.

Homeowners who treat their sewage in a septic tank must be careful to limit their use of household chemicals. Over-use of soaps, detergents and cleaning solvents, because they kill beneficial bacteria, can make septic tanks inefficient and a source of contamination. According to the EPA, septic tanks that do not work properly are a major source of groundwater contamination (EPAc).

1.3.10 Impact of Nonhuman Activity on the Rio Grande

Birds and other wildlife, naturally attracted to water, are common inhabitants of the Rio Grande bosque. In addition to large numbers of resident and over-wintering birds, the Rio Grande corridor is a “fly-through” for *hundreds of thousands* of birds migrating between Canada and South America. Although birds control insect populations and spread seeds in their fecal matter, their droppings contain many different potentially pathogenic microbes. Many of these pathogenic organisms are naturally part of the bird’s gut microflora, and can be transmitted to humans in contaminated water, air, or food.

In addition to birds, the river and the surrounding bosque are home to many varieties of fish, lizards, turtles, and snakes as well as beaver, rabbits, mice, rats, and other small mammals. Each of these animal species contributes gut-derived microbes when their fecal matter is directly deposited or washed into the river (see Table 1-3). Many of these microbes can produce disease when they are transmitted to humans in contaminated water and food.

Table 1-3: Some Potentially Waterborne Pathogens Associated with the Feces or Urine of Birds and Other Wild Animals (Schlossberg, 1999)

Animal Species	Potentially Waterborne Pathogens
Birds	Cryptococcus, Salmonella, *Yersinia pseudotuberculosis*
Fish	Campylobacteria sp., Edwardsiella, Vibrio sp.,HAV, Norwalk virus, rotavirus
Reptiles	Salmonella, Campylobacteria, Edwardsiella
Rodents	Salmonella, Leptospira sp.
Mammals	Giardia, *Yersinia enterocolitica*, Campylobacteria sp.

1.3.11 Domestic Animals

The banks of the Rio Grande and the canal systems are an attractive place to live, farm, and raise animals (Photo 1-7). However, according to the New Mexico Water Quality Commission, over-grazing, poor management of stockyard waste, and flood irrigation produce a highly contaminated runoff that badly compromises the quality of the state’s surface water supplies.

Between Angostura and Los Lunas there are dairy farms, stockyards, horse stables, and many private residences that house a variety of farm animals on their property (Photo 1-8). With respect to animal waste BMP, commercial properties are required to conform to state and federal water quality regulations. However, on residential properties, these laws do not apply. Homeowners need only conform to the local zoning laws that regulate the number of animals. Livestock management activities along the river and canals can contribute pathogens to the river, and should be considered in future TMDL scenarios for the middle Rio Grande.

1.4 Regulatory Background

In 1986 the EPA issued Draft Implementation Guidance for Ambient Water Quality Criteria for Bacteria (EPA 1986) to assist states, territories, and tribes in developing water quality criteria for bacteria. According to this guidance, water quality criteria for bacteria was based upon certain concentrations of indicator organisms which was not to be exceeded (EPA 2000). EPA recommended that *E. coli* are best suited for predicting the presence of gastrointestinal illness-causing pathogens. In their recent update to the 1986 Criteria document, the EPA recommends the continued use of *E. coli* for measuring the potential presence of pathogens in surface water. Studies have shown the *E. coli* is the best indicator organism for measuring water quality, as it shows a very strong relationship to swimming associated gastrointestinal illness. For those states that have not adopted *E. coli* in their NPDES permits, and have used fecal coliforms as indicators of pathogens, EPA recommends continued use of fecal coliforms for developing TMDLs. Currently the City uses fecal coliforms as the measure of pathogens in their effluent, and will continue to measure fecal coliform levels until the State of New Mexico adopts *E. coli* or EPA promulgates a national *E. coli* standard.

1.5 Endangered Species

The focus of this report is not to address issues about endangered species, but some mention is appropriate of their presence and about any microbial related surface water quality aspects that are the focus of this report. The Rio Grande Silvery Minnow (RGSM), a listed endangered species, is indigenous within the middle Rio Grande as are many endangered bird species and one endangered ferret. The middle Rio Grande is within the 163 mile river stretch of critical habitat listed for the RGSM. The middle Rio Grande / Albuquerque area is characterized as a more perennial stretch than further south, thus generally aiding the minnow's survival. A biological assessment addressing the City's stormwater runoff into the Rio Grande was performed by consultants in 1999. EPA is presently evaluating that report. The biological evaluation did conclude that no direct effects are expected due to the City's stormwater discharge on the RGSM or its designated critical habitat. An additional biological evaluation focusing on the City's reclaimed domestic wastewater discharge is also being prepared addressing the effects, if any, on listed or threatened endangered species. Of note is that the City's SWRP discharge routinely indicates non-toxic results in 100% effluent in identical sensitive biomonitoring tests required under the NPDES permit.

Photo 1-1: Albuquerque's Southside Wastewater Reclamation Plant

Photo 1-2: Bernalillo Wastewater Treatment Plant

Photo 1-3: Isleta Diversion Dam on the Rio Grande

Photo 1-4: Urban sources of runoff

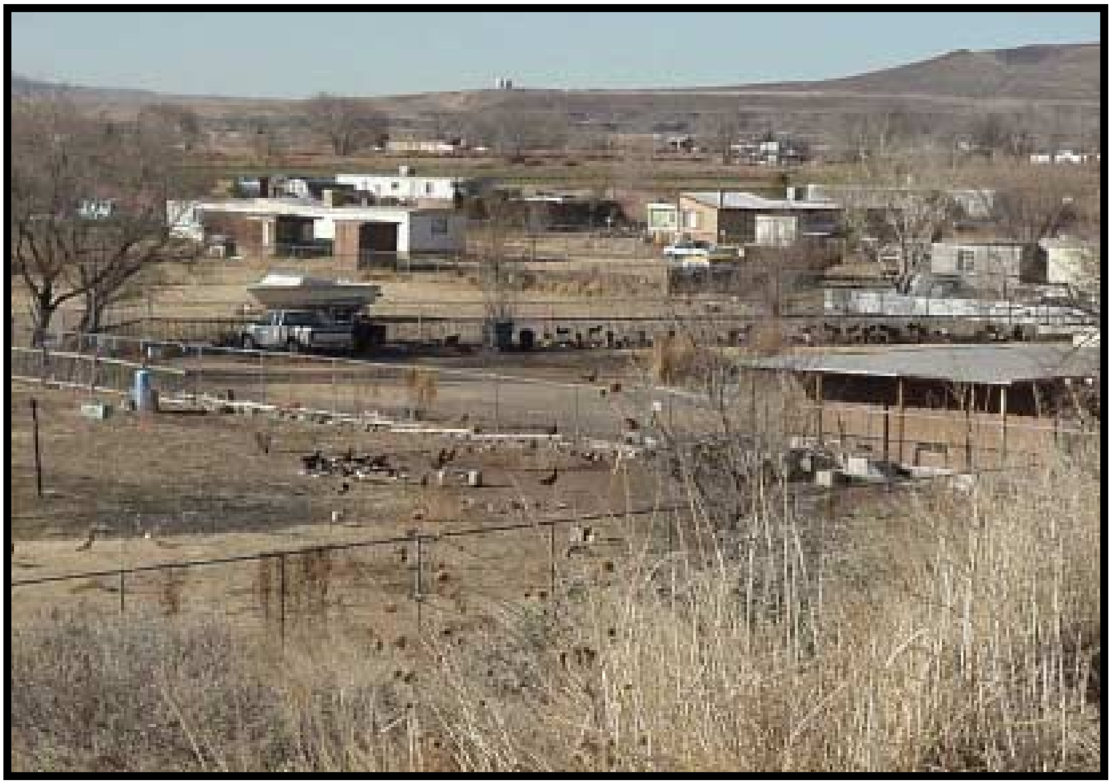


Photo 1-5: Chickens and livestock adjacent to the Rio Grande

Photo 1-6: Stormwater drain to the Rio Grande

Photo 1-7: Residential area along canal

Photo 1-8: Private residence with pasture along Rio Grande

Section Two

Section 2
Study Approach

2.1 Approach and Methods

The approach used to conduct the proposed investigations included field and literature research, as well as laboratory-based techniques used to assess bacterial indicators of water quality. Field studies provide information about the historical aspects of Rio Grande water quality and provide new information that will help to delineate the reasons for and the sources of microbially contaminated runoff, seepage, and septage. Field studies also included site reconnaissance at each of the sampling locations. This reconnaissance included a survey of the area to determine the potential for site runoff to the river or canals, uses (e.g. fishing) occurring in the area, and potential sources (e.g. livestock operations) that could contribute to water quality problems in the river and canals.

Recent literature were reviewed to determine the most recent trends in assessing water quality using microbial indicators. Additionally, the literature was reviewed to assess current methods for identifying specific pathogens, and whether they could be implemented in this study.

Laboratory-based research, using both established and innovative methods for the assessment of waterborne bacteria, was performed to determine the prevalence of potentially pathogenic bacteria in the Rio Grande. One of the goals of this study is to determine presence or absence of gut-derived pathogens upstream and downstream from the SWRP. When evaluated in conjunction with the field studies, this information will provide insight concerning microbial sources and potential strategies for river water improvement. Microbial parameters to be measured include:

- Total and fecal coliforms
- *E. coli*
- Fecal streptococci
- Hydrogen-sulfide producing bacteria
- *E. coli 0157:H7*

These organisms were selected based upon their inherent pathogenicity or their capabilities to indicate the presence of pathogens.

2.2 Sampling Locations

Figure 2-1 shows the eight water quality sampling locations. These stations were selected based upon the availability of historical data for these sites, proximity to major input sources, and accessibility for sampling. The following provides a more detail discussion of each of these sites:

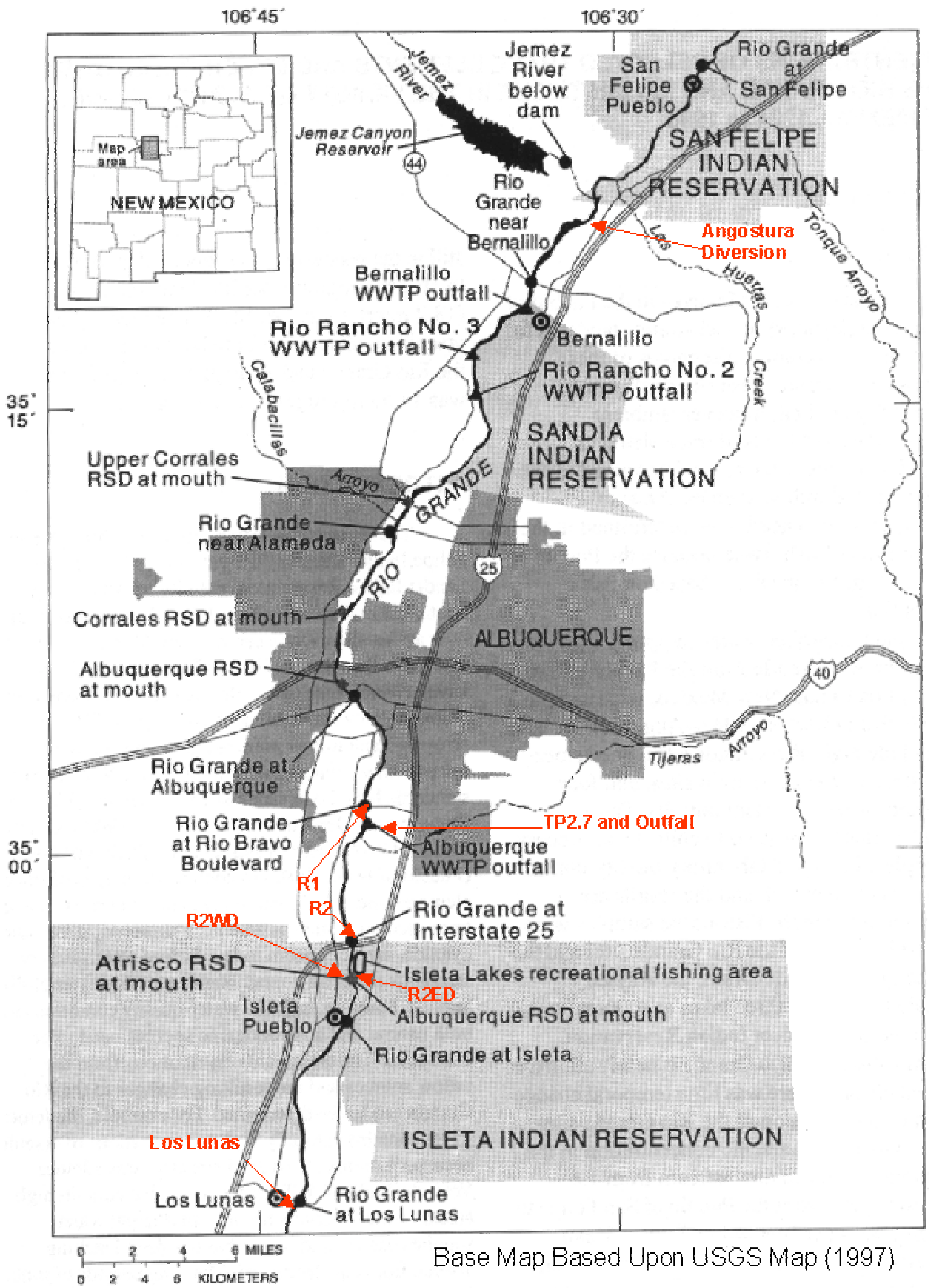


Figure 2-1 Study Area and Eight Water Quality Sampling Locations

2.2.1 Angostura

The Angostura diversion off the Rio Grande, the northernmost site in the river sampling set, was built in 1938 as a post-depression era Works Progress Administration project. Diversion water is under consideration as a source of drinking water for the City of Albuquerque. The Angostura diversion is south of the Village of Algodones as well as the San Felipe and Santa Ana Pueblos. The source of water for Angostura is Cochiti Dam located north of the diversion. A clear drainage canal that runs north and east of the diversion intersects with the spillway channel running south of the diversion.

The land north of the spillway is rocky and highly eroded, as is the land on both sides of the spillway channel. The surrounding area, a dumping ground for crushed rock and cement, is divided by road cuts and is vegetated by scrubby weeds and other noxious plants. Approximately 1000 feet from the spillway channel is a large stand of mature cottonwood trees. The area is popular for duck hunting along the river and fishing behind the diversion structure.

Figure 2-2: Angostura looking north toward the spillway.

For the first seven months of the River Study (July-January), water was sampled downstream from the diversion in the southern end of the diversion channel. Water sampled here is commingled river and clear-canal water. Starting in February 2000 water samples were taken on the north side of the diversion. Water taken from this location is Rio Grande water.

2.2.2 Rio Bravo Bridge - R1

Water collected at the north side of the Rio Bravo Bridge demonstrates the influence of people, agriculture, wildlife, traffic and businesses on the river as it flows through the City of Albuquerque. This site is located about half a mile upstream of the City's wastewater treatment plant, and has been sampled extensively in the past.

2.2.3 SWRP Effluent Channel TP2.7

SRWP discharge is collected from a siphon trap just before the water enters the discharge channel to the river. This sample represents SWRP-treated water and is unaffected by the conditions of the river.

2.2.4 SWRP Outflow Channel

Due west of the TP2.7 is the outflow to the river. This site was added to the sampling protocol when it was noted that birds, waterfowl, fish and other animals inhabit the deep channel created by the SWRP outflow to the river. The area is frequented by local anglers, as evidenced by bait supplies and fishing paraphernalia (e.g. fishing line) left behind, and the observance of several anglers during site reconnaissance.

Figure 2-3: TP2.7 Sampling port behind fence and outflow channel

Heavily eroded and undercut embankments, created by the continuous flow of water originating from the SRWP, border the channel. The bottom and rocky sides of the Outflow, covered by a biofilm of algae and bacteria, give the outflow a distinctly green color. This site is currently under design to be improved significantly with upgrades including visitor fish viewing stations along the channel.

Many wild birds, ducks, and large fish are found both in the Outflow and by the mouth of the Outflow to the river. The area is extensively used in the winter time by waterfowl, and during the summer months many small and large fish can be seen swimming in the water.

2.2.5 I-25 Bridge - R2

Water sampled on the south side of the I-25 Bridge, about three miles south of the SWRP, represents discharge from the SWRP in addition to upstream river flow, run-off, and seepage produced by people, agriculture, wildlife, traffic, industry, and businesses.

Figure 2-4: R2, located three miles south of the SWRP, is a broad expanse of braided river bordered on either side with trees and underbrush.

2.2.6 Atrisco Riverside Drain - R2WD

R2WD is the west drainage canal located approximately 1000 feet west of the R2 site. This site, demonstrating habitation commonly seen along many stretches of the Rio Grande canals, shows a small grouping of homes located close to the water. Farm animals are housed on the adjoining properties and on occasion sheep and other animals have been observed grazing on canal embankments.

2.2.7 Albuquerque Riverside Drain - R2ED

The east canal is approximately 1000 feet east of the R2 site. The borders of the canal, heavily overgrown with brush and tumbleweed, are flanked on either side by trees. Isleta Lakes, a series of groundwater fed commercial fishing ponds is located near by. The water in the R2ED canal moves slowly, thus limiting oxygenation as well as permitting the collection of paper, bottles, cans, and other trash between the rocks.

Figure 2-5: Flow through the R2ED canal is controlled by water gates.

2.2.8 Los Lunas

Los Lunas is the downstream terminus to the River Study. In addition to the conditions encountered upstream, seepage and run-off originating from the Isleta Pueblo, Village of Bosque Farms, and the Village of Los Lunas also influence water quality. The sample is collected on the south side of the Los Lunas Bridge. At this point the river is broad, shallow, and flanked on both sides by heavy over-growth and trees.

Figure 2-6: The Los Lunas sample is collected off of the Los Lunas Bridge.

2.3 Historical Records

Over the years the Rio Grande has been assessed and monitored by a variety of government agencies and academic institutions. Their data were reviewed and evaluated in the context of our current findings.

2.3.1 Birds and Other Animals

Potential microbial contamination to the Rio Grande originating from bird, wild animal and domestic animal wastes was assessed by:

- Review of brochures, published by various city, state or federal agencies, that describe the birds and wildlife living in protected areas along the Rio Grande,
- Review of the Annual Christmas Bird Count and local Audubon Society reports, and
- Consultation with local state and federal wildlife agencies.

The Rio Grande is a major flyway for many migratory birds, and during the winter, many waterfowl use the Rio Grande and the surrounding bosque for foraging and habitat. Seasonal bird populations exceed fifty to eighty-thousand birds of different species.

2.4 Epidemiology

To evaluate the public health impact of the Rio Grande on the residents of the State of New Mexico, information concerning incidents of reportable waterborne diseases and risk factors involved in their transmission were collected from various sources. Incidents of waterborne disease in New Mexico, the Rocky Mountain Region, and the United States were compiled from the Centers for Disease Control’s Morbidity and Mortality Weekly Reports. Data was collected for 1998, 1999 and 2000.

Locally reported incidents of potentially waterborne diseases were received from the Epidemiology Division of the State of New Mexico Health Department. Their data includes identification of the infectious microbe, patient residence, and if exposure to contaminated water may have contributed to illness.

To get meaningful comparative information from the raw reported data it was necessary to calculate the frequency for specific waterborne diseases based on the population of potentially affected people. Rate of occurrence for potentially waterborne disease is reported as frequency per 100,000 people.

2.5 Field Methods

2.5.1 Sampling

Water samples were taken twice a month from July 1999 to June 2000. A composite sample, made from three representative grab samples, was composed in the field. The composite sample was field-assessed for temperature and pH.

2.5.2 Sample Preparation and Preservation

Two – one hundred milliliter volumes of a composite sample from each site were taken to the laboratory in sterile sodium thiosulfate – containing bottles. The bottles, stored in an ice-chilled chest, were brought to an accredited laboratory for microbial analyses. Samples were processed for a variety of waterborne microbes within 4 hours after collection. Samples were refrigerated until all of the analyses were complete.

2.6 Laboratory Methods

Laboratory-based research, using both established and innovative methods for the assessment of waterborne bacteria, was performed to get data concerning the prevalence of potentially pathogenic bacteria in the Rio Grande. The methods used to quantitatively evaluate the presence and prevalence of potentially waterborne pathogenic bacteria in the Rio Grande are Most Probable Number (MPN) assessments for hydrogen-sulfide producing bacteria, total coliforms, *E. coli*, and fecal streptococci. A presence / absence method was developed to assess the presence of *E.coli* 0157:H7 in Rio Grande water. Fecal coliforms were isolated and enumerated by membrane filtration. The results from these tests give insight concerning potential sources of non-point microbial runoff.

The particular organisms chosen for assessment of Rio Grande water give the “big-picture” view of the presence of potentially gut derived bacteria that originate from humans, domestic and wild animals.

2.6.1 Most Probable Number Methods

The Rio Grande bacterial assessment takes advantage of several MPN methods. The MPN methods were chosen because it is possible to get quantitative information without having to do time consuming and labor-intensive dilutions and plate count methods. The MPN method is based on a statistical determination of the number of fecal coliforms and fecal streptococci per 100 milliliters of water. The 15-tube MPN table provides the 95% confidence limit for each index value. The MPN methods used in the Rio Grande study are:

- Lauryl tryptose (LT) tubes with 4-methylumbelliferyl-β-d-glucuronic acid (MUG) for total coliforms and *E. coli*,

- PathoScreen tubes for hydrogen-sulfide producing bacteria that include *Salmonella, Proteus, Citrobacter, Klebsiella, Clostridium,* and *Edwardsiella*

- Azide dextrose broth and bile esculin plates for fecal streptococci

2.6.2 Lauryl Tryptose with MUG for Total Coliforms and *E. coli*

The LT with MUG, HACH Company procedure (8091) is a MPN method that measures the number of total coliforms and *E. coli* in a sample. The presence of turbidity and gas is a positive result for total coliforms. The fluorescence of MUG confirms the presence of *E. coli* in the sample. LT-MUG tubes were read 24 and 48 hours after inoculation and incubation at 35 degrees Celsius. Total coliforms and *E. coli* were determined using the 15 tube MPN index. Data is expressed as the number of total coliforms or *E. coli* per 100-ml sample after 48 hours incubation at 35 degrees Celsius

2.6.3 PathoScreen for Hydrogen-Sulfide Producing Bacteria

Assessment for hydrogen-sulfide producing bacteria was done following HACH method 10032. The formation of a black precipitate demonstrates a positive result. The number of hydrogen-sulfide producing bacteria was determined using a 5 tube MPN index. Data is expressed as the number of hydrogen-sulfide producing bacteria per 100-ml sample after 24 hours incubation at 35 degrees Celsius.

2.6.4 Bile Esculin Confirmation for Fecal Streptococci

Bile esculin confirmation for fecal streptococci followed procedure 9230B as described in Standard Methods for the Examination of Water and Wastewater, 20th edition (1998). Growth, as demonstrated by turbidity in azide dextrose broth, is the presumptive test for fecal streptococci. The presence of fecal streptococci in presumptive-positive tubes is confirmed by streaking on bile esculin agar and the production of a black precipitate after incubation for 24 hours at 35 degrees Celsius. Data is expressed as the number of fecal streptococci per 100 ml sample.

2.6.5 Rainbow 0157 Agar for *E. coli* 0157:H7

The presence / absence of *E. coli* 0157, a hemorrhagic and verotoxin-producing strain, was assessed as part of the Rio Grande Study as this pathogen is normally associated with food contamination, and is usually associated with contamination from wildlife and livestock. Because there are no standard methods to detect *E. coli* 0157:H7 in surface water, a technique was used that takes advantage of the selectivity of the LT tubes and the selective and differential properties of Biolog's Rainbow 0157 media.

Organisms from MUG positive LT tubes were streaked on Rainbow 0157 media. The LT media selects for coliforms, and tubes that are MUG-positive contain *E. coli*. Verotoxin-producing *E. coli* are visually differentiated from other bacteria by the color of the colonies on Rainbow 0157 agar (Table 2-1).

Table 2-1: Expected Results on Rainbow Agar 0157*

Organism	**Colony Coloration**
*E. coli 0157:*H7	Black-gray
*E. coli 0157:*H7 glucuronidase positive	Purple-blue
*E. coli 026:*H11	Purple-magenta
*E. coli 048:*H21	Purple
E. coli 0111:H- or 0111:H8	Violet or gray
Non-toxigenic *E. coli*	Pink or magenta
Enterococcus faecalis	white

*** Rainbow Agar 0157 Technical Information, Biolog, Hayward California.**

Gray or deep purple colonies are considered presumptive positive for *E. coli* 0157:H7. Although not an established confirmatory method, purple or gray colonies are further tested with Kovac's reagent. Kovac's positive bacteria produce indole from the amino acid tryptophane, a characteristic that is used to differentiate *E. coli* from other enteric bacteria. Samples that demonstrate gray or purple colonies on Rainbow 0157 agar as well as test positive with Kovac's reagent are recorded as positive for *E. coli* 0157:H7.

Figure 2-7: Positive (left side) and negative (right side) test for *E. coli* 0157:H7.

2.6.6 Membrane Filtration for Fecal Coliforms

The membrane filtration method for fecal coliforms was used because it is the standard method used to assess water quality in the State of New Mexico. It was important to have laboratory-based data that could be directly compared to the State's historical data. A single 100-ml (1x10-2-dilution) sample was used to test river water for fecal coliforms using the method described in the Water Quality Laboratory SOP MI-001 (1998). Due to the non-regulatory nature of this study, a single 100-ml sample was prepared to represent each of the eight testing sites.

Section Three

Section 3
Results

3.1 Site Reconnaissance

Each of seven initial sampling sites was field inspected eight times over the course of the Rio Grande Study. An eighth site, the SWRP Outflow to the Rio Grande (i.e. at the Outflow channel directly adjacent to the Rio Grande), was added in February and was field inspected five times. In addition to the individual site inspections, visual inspections from the ground and the air along the entire length of the study area were also conducted. Water samplings occurred on 24 different dates, July 1999 to June 2000 (bimonthly), at the seven original sites, and on 10 different dates for the eighth site.

Sites north and upstream from the SWRP are:

- Angostura diversion – water collected on the south and north sides of the diversion,
- R1 – river water flowing under the Rio Bravo Bridge,
- TP2.7 – the SWRP sampling port before entry into the Rio Grande and
- Outflow – the channel from the SWRP to the Rio Grande

Sites south and downstream from the SWRP are:

- R2 – river water flowing under the I-25 Bridge
- R2WD – the drainage canal west of R2
- R2ED – the drainage canal east of R2
- Los Lunas – river water flowing under the Los Lunas Bridge

3.1.1 Overview of Land Use and General Observations

There is both uniformity and variation with respect to land-use in the area bounded by the Angostura and Los Lunas sampling sites. Transportation-related facilities such as the Santa Fe Railroad tracks, pedestrian trails, and frontage roads are unifying features throughout the approximately 40-mile extent of the study area. Another consistent Rio Grande land-use feature is the practice of flooding land with river water to irrigate crops, grazing fields, and lawns. Flood-irrigation is seen both in rural and urban settings along the Rio Grande.

Land in the northern third of the study area (Angostura to Alameda) is primarily used for agriculture as well as rural and low-density housing. However, it is apparent from the visual inspection, historical and aerial study, that high-density housing and other indicators of urban growth and development are quickly approaching the river's borders.

From Angostura south to Alameda there are a number of dairy farms, riding and boarding stables, plant nurseries, small-scale produce farmers, and many residential properties where people keep animals and grow fruits and vegetables for their own use.

Two pueblos, Santa Ana and Sandia, are currently making many land-use changes. The Santa Ana Pueblo, located west of the Rio Grande, is the site of the Santa Ana golf course. The Pueblo recently built a multi-acre, grassed soccer complex and is currently in the process of building a large hotel and resort that will overlook the Rio Grande. The Sandia Pueblo, located approximately 2 miles east of the river, is in the process of building a large amphitheater and a larger casino.

The middle third of the Rio Grande study area demonstrates a complex mixture of rural, suburban, and urban uses of land. South of the Alameda Bridge to the northern border of the SWRP are the North Valley communities, the Rio Grande Nature Center, the Zoo, the Botanical Gardens, and the Aquarium. There is an incongruous intermingling of industry, high-density housing, and homes in nearly rural settings in this area.

The southern third of the Rio Grande study area, extending from the SWRP Outflow to Los Lunas, transitions from a high-density urban environment to a low-density rural environment. However, the communities of Bosque Farms and Los Lunas are rapidly loosing their rural character and becoming a suburban extension for the City. The Isleta Pueblo and the SWRP are found in this reach. The Isleta Pueblo is located downstream of the SWRP and is located on both sides of the Rio Grande. The Isleta golf course (Photo 3-1) is located within a half a mile of the river, and is perched on ground higher than the river and canals. Golf courses elsewhere have been found to directly contribute runoff containing nutrients and other substances to watercourses.

The aerial view (Photo 3-2) of the Rio Grande encompassing the area between the northern and southern boundaries of the Rio Grande study area demonstrates a highly diverse landscape. Russian olive trees, easily identified by their characteristic silvery-green foliage, line much of the river’s perimeter. Other types of trees such as willows and cottonwoods, and low-lying plant growth were also observed.

Although most of the river is bordered by riparian growth, there are significant gaps in the continuity of this protective edging. Not only are there obvious breaks in the riparian strip due to urban impact and encroachment, but patches of bare earth can be seen between the trees. Some of this may be due to the City’s efforts to reduce the udergrowth to limit bosque fires. It appears that much of the protective riparian border is devoid of the scrubby undergrowth needed to limit runoff and erosion.

Underwater sandbars were clearly visible from the air and many stretches of the river demonstrated a braided appearance. In addition there were large expanses of exposed sand and silt. Many of these exposed areas were heavily vegetated and are an indication that low water is a seasonal Rio Grande feature.

Throughout the year's reconnaissance trips, anglers (Photo 3-3) were observed fishing at various sites along the Rio Grande. Favorite fishing sites are the waters behind the Angostura diversion structure, underneath the Rio Bravo and I-25 bridges, and the SWRP outflow channel.

3.1.2 Point Sources

Wastewater treatment facilities located in Albuquerque, Rio Rancho, Bernalillo, and Los Lunas are well-defined point sources of discharge to the river. Because these are NPDES-permitted facilities, their discharge to the river is well characterized.

3.1.3 Nonpoint Sources

Farm animals are housed on commercial and residential properties along the Rio Grande (see Table 3-1). Sites extending from Angostura to Los Lunas where animals are housed include dairy farms, stockyards (Photo 3-4), horse stables, and many private residences (Photo 3-5) having a variety of animals. Many property owners also store old tanks, scrap metal (Photo 3-6), cars, and building supplies in the same area where horses and cows are stabled.

Table 3-1: Observed Animals Along the Middle Rio Grande

Animal	Location
Cows	Throughout
Horses	Throughout
Pigs	Rio Bravo Bridge and Isleta Blvd.
Goats	Throughout
Sheep	Throughout
Chickens	Throughout
Ducks	Throughout
Emu	North of Rio Grande Nature Center
Ostriches	North of Rio Grande Nature Center
Llamas	North of Rio Grande Nature Center
Peacocks and Peahens	Near Rio Bravo Bridge
Camels	North of Rio Grande Nature Center

Manure piles were commonly observed on properties where animals were housed. These piles, visible from the pedestrian trail, were neither covered nor were there barriers to prevent seepage and runoff from entering the Rio Grande.

A feature commonly observed on many residential properties were sloping and sometimes grassed-over humps of dirt which mark the location of septic tanks. Improperly working or poorly maintained septic tanks are typically major sources of contamination to groundwater and surface water sources.

The aerial assessment identified several manmade and natural sources of potential non-point runoff to the Rio Grande. The Cottonwood Mall (Photo 3-7) located approximately a half mile east the Rio Grande is a prime example of a large impervious surface that prevents the normal transport and absorption of water. Runoff instead flows almost immediately to the river. The Cottonwood Mall property including the buildings and parking lot, covers over 91 acres. The parking lot has room for nearly 6000 cars (Benvenuto, 2000). Construction of the mall, in what was once an isolated and under- developed part of Albuquerque, has attracted an influx of other businesses located north, west, and south of the Cottonwood Mall, thereby creating an even larger area of impervious surface.

The Santa Ana and Isleta golf courses (Photo 3-8) are potential sources of non-point runoff to the Rio Grande. The Santa Ana golf course is located adjacent to the to the town of Bernalillo, and ¾ of a mile west of the river. The Isleta golf course is located approximately 6 miles south of the SWRP and approximately ¾ of a mile east of the Rio Grande. Because of the hot, dry climate, the golf course turf is managed through intensive watering and application of fertilizer. The golf courses, situated on sloping terrain approximately 100 feet above the river, may produce a nutrient-rich runoff that can potentially stimulate the growth of microbes already present in the Rio Grande.

A variety of industries and businesses are found throughout the sampling range of the study area. These businesses include green houses, metal recycling, construction, mineral processing, sand and gravel, oil storage, and animal boarding facilities.

The aerial perspective revealed large expanses of bare and compacted land. These areas include newly developed neighborhoods in the communities of Rio Rancho (Photo 3-8) Ilantitos, and Bernalillo, areas north, west, and east of Angostura, and housing developments south of the SWRP in Bosque Farms and Los Lunas. Junkyards and metal recycling facilities also demonstrated large expanses of bare and compacted soil.

3.1.4 Potential Sources of Illegal Dumping

According to SWRP personnel, illegal dumping into stormdrains, sewers, or directly into the river is a common problem (Gonzales, 2000 and Padilla, 2000). Although citizens are sometimes involved in illegal or inappropriate disposal of organic wastes, the worst offenders are usually a few businesses involved in the repair and maintenance of septic tanks, portable toilets, sewer lines, and grease traps. These businesses are required by law to deliver the liquid waste to the SWRP for processing, but some of them, to avoid having to pay for this service, illegally dump the waste elsewhere. There are approximately 35 different businesses that offer services involving septic tank pumping, maintenance, and repair; portable toilet rental and maintenance; grease trap maintenance; waste oil disposal; and sewer line maintenance and repair. The City has fined and even taken to court past violators who did not adhere to city ordinances.

3.1.5 Summary of Field-Based Results

The site assessment revealed many point and non-point sources of runoff, seepage, and septage. The major sources of potential microbial contamination to the Rio Grande and the adjoining canals include:

- Farm animals housed on small properties
- Septic tanks
- Manure management and composting on commercial and non-commercial properties
- Fertilizer and pesticides use on non-commercial property
- Illegal or questionable dumping practices
- Scrap metal yards
- Large areas of impervious and compacted surfaces
- Disruption of the riparian zone
- High density housing
- High density business development
- Golf courses
- Railroad tracks
- Man-made ponds and lakes
- Unvegetated connections between agricultural property, drainage/irrigation canals, and the river

3.2 Historical Findings

Historical-based findings include “old” information as well as recent information researched and compiled by other individuals, institutions, or government programs. The historical findings described in this report include public information of record as well as information researched and compiled by the United States Department of Agriculture (USDA) Forestry Service, the City of Albuquerque, and the State of New Mexico.

3.2.1 Birds and Other Animals

Wastes originating from birds, mammals, amphibians, and reptiles living near or in the Rio Grande contaminate water with potentially pathogenic bacteria, viruses, and parasites. *Salmonella*, *Leptospira*, *Giardia*, and *Cryptosporidium* are examples of some pathogenic microbes that are carried and transmitted in animal waste.

Over 50,000 migratory waterfowl and 40,000 sandhill cranes (Photo 3-9) pass through or winter-over in the middle Rio Grande region each winter (Albuquerque Journal, January 8, 2000). This corresponds to a significant daily contribution of 1.98 x 10^{14} (198,000,000,000,000) waterfowl-borne fecal coliform bacteria. Additional microbial introductions are made by thousands of other indigenous and migratory bird species. According to the Annual Christmas Bird Count conducted in Albuquerque on December 19, 1999 there were over 21,000 individual bird sightings that represented 49 different bird species (BirdSource, 1999).

The number of middle Rio Grande residential and migratory birds obviously affects river microbial water quality, other parts of the environment, and the birds themselves. Large numbers of birds living under stressful conditions – adverse weather and scarce food, tend to spread disease within their local populations.

Avian cholera, a disease believed to have contributed to the deaths of many thousands of middle Rio Grande migratory birds over the 1999-2000 winter, is attributed to cold weather and high flock densities (Albuquerque Journal, January 8, 2000). Avian cholera is caused by infection by the bacterium *Pasteurella multocida*, and is one of the most common diseases among North American waterfowl (Avian Cholera Information, 2000). Although most birds and mammals can become infected with host-specific strains of this organism, the Type I strain infects ducks, geese, coots, gulls, and crows (UMESC, 2000). Death from the disease is rapid and birds literally fall out of the sky (UMESC, 2000). Humans are not at high risk for infection with the Type I strain (UMESC, 2000).

3.2.2 Leaking Underground Storage Tanks

Geographical Information System (GIS) information retrieved from the City of Albuquerque website shows many potential sources of seepage and runoff generated by LUSTs located at sites near the Rio Grande (Photo 3-10). The majority of these sites are located between the Rio Bravo Bridge (R1) and the I-25 Bridge (R2) (City of Albuquerque, 2000). LUSTs often leach petroleum products that support bacterial degradation activity causing marked chemical and biological decline of ground and surface water quality. Additionally, since petroleum products provide some nutritional value to microbes, they can support the growth of bacterial populations already present in Rio Grande water.

3.2.3 Septic Tanks

North of the Angostura diversion are the communities of Algodones and Llanito. In both of these rural communities all of the residents use septic tanks for the disposal and treatment of domestic wastewater. Because the depth to groundwater in Algodones is only four to ten feet, septic tanks are a potential source for groundwater contamination. South of Algodones is the unincorporated Village of Llanito. The clear drainage canal passes through the east side of the village, eventually connecting to the Angostura diversion channel. Depth to groundwater in this area varies, but is on the order of 15 feet (Barela, 2000).

According to the Albuquerque Journal, over 1,800 North Valley homes use septic systems to treat their domestic wastewater. Septic tank failures in the North Valley are common. Almost 60% of the homes in the Dietz Farm area have had a septic tank failure in the past five years (Albuquerque Journal, March 3, 1999).

3.2.4 Water Quality and Waterborne Microbes

Data related to Rio Grande water quality are documented in reports produced by the USGS Water Resources Data New Mexico 1997. The USGS report does not document any microbial data taken at the Albuquerque discharge gage 08330000 (Central Avenue and the Rio Grande). However, at the Isleta gage (USGS 08331000) four measures of microbial contamination were taken between the years 1996 and 1997 (see Table 3-2).

Table 3-2: Microbial Assessment of Rio Grande Water at the Isleta Gage 08331000 (USGSb)

Date	Fecal Coliforms CFU/100 ml	Fecal Streptococci CFU/100 ml
November 5, 1996	5000	570
March 5, 1997	43	460

From 1986 to 1999, the Albuquerque Public Works Department sampled and assessed SWRP and Rio Grande water in preparation for NPDES permitting. The fecal coliform results from R1, TP2.7, and R2 are shown in Table 3-3. These results indicate that fecal coliforms were found both upstream and downstream from TP2.7. Of the three locations sampled, TP2.7 measured the lowest rate of fecal coliforms, and R2 which is downstream of TP2.7 measured the highest rate. Because TP2.7 discharged a lower level of fecal coliforms than locations downstream, it could not have been the source of fecal coliform contamination in the river. Potential sources may include wildlife, LUSTs, septic discharges, concentrated animal facilities, and runoff from private properties.

Table 3-3: Historical Fecal Coliforms (CFU/100 ml) Upstream and Downstream from the SWRP (Glass, 2000)

Date	R1	TP2.7	R2
1/7/97	60	13	260
2/6/97	18	14	134
3/5/97	66	8	92
4/22/97	260	9	140
4/23/97	120	22	105
6/24/97	60	11	135
7/29/97	23000	19	4600
8/28/97	900	18	800
9/12/97	Not available	400	2700
10/1/97	1500	13	250

Table 3-3 (continued)

Date	R1	TP2.7	R2
11/25/97	70	21	290
12/23/97	100	500	500
2/18/98	220	340	340
3/18/98	140	520	520
4/15/98	40	1	1
11/24/98	100	400	400
3/23/99	100	60	60

Both in the Water Quality in New Mexico, and more recently in the 2000-2002 State of New Mexico List for TMDLs, the middle Rio Grande is assessed by probable sources of pollution and its affect on water use (State of New Mexico, 2000). According to these documents over 38 miles of the middle Rio Grande region is affected by fecal coliforms originating from municipal point sources, urban runoff, and storm sewers. The relative contributions from these sources have not been evaluated to determine which category influences the river the most (State of New Mexico, 1996).

3.2.5 Ambient Microbial Water Quality Standards Comparisons

Three different entities have established water quality standards for the surface waters in the middle Rio Grande area: (1) State of New Mexico-Water Quality Control Commission, (2) Pueblo of Sandia and (3) Pueblo of Isleta. Within each entity standards have been set for certain designated uses along with ambient water criteria to protect those uses. Tables 3-4 and 3-5 compare those uses related to microbial criteria.

Table 3-4: Water Quality Standards- Middle Rio Grande

Elephant Butte Reservoir Upstream to Alameda Bridge - Encompasses Isleta Pueblo reach and most of Albuquerque urban area in this study

State of New Mexico Water Quality Standards	
Uses	Fecal Coliform Ambient Standards
Irrigation and Secondary Contact	1000 CFU/100 ml monthly geometric mean and 2000 CFU/100 ml for a single sample
Pueblo of Isleta Water Quality Standards	
Uses	Fecal Coliform Ambient Standards
Primary Contact Ceremonial and Primary Contact (April-September)	100 CFU/100 ml monthly geometric mean and 200 CFU/100 ml for a single sample
Secondary Contact Recreational and Primary Contact (October - March)	200 CFU/100 ml monthly geometric mean and 400 CFU/100 ml for a single sample
Agricultural Water Supply for Irrigation and Livestock	1000 CFU/100 ml monthly geometric mean and 2000 CFU/100 ml for a single sample

Table 3-5: Water Quality Standards- Middle Rio Grande

Alameda Bridge Upstream to Angostura Diversion Works – Encompasses Sandia Pueblo reach and north through the Town of Bernalillo and Village of Algodones

State of New Mexico Water Quality Standards	
Uses	**Fecal Coliform Ambient Standards**
Irrigation and Secondary Contact	200 CFU/100 ml monthly geometric mean and 400 CFU/100 ml for a single sample
Pueblo of Sandia Water Quality Standards	
Uses	**Fecal Coliform Ambient Standards**
Primary Contact Ceremonial and Primary Contact (April-September)	100 CFU/100 ml monthly geometric mean and 200 CFU/100 ml for a single sample
Secondary Contact Recreational and Primary Contact Recreational (October - March)	200 CFU/100 ml monthly geometric mean and 400 CFU/100 for a single sample
Agricultural Water Supply for Irrigation & Livestock	1000 CFU/100 ml monthly geometric mean and 2000 CFU/100 ml for a single sample

The above tables show a wide variation between adopted State of New Mexico and Pueblo water quality standards for this common water body. The largest distinction pertains to the practice of intentional ingestion of raw (untreated) river water by the Pueblos, which is not a recognized designated use by the State of New Mexico. The State of New Mexico standards do not apply within the Pueblo boundaries. The State of New Mexico does recognize ceremonial practices under the State's definition of "primary contact use" but this is not one of the State's designated uses for the middle Rio Grande.

It is not recommended, from a public health perspective, to drink raw (untreated) river water. This statement is based on the documented microbial species, concentrations and many sources of microbial contamination found in most river systems including the middle Rio Grande. In discussing ambient river conditions, EPA has stated that "water with fecal coliform bacteria counts above 200 should not be ingested. The Safe Drinking Water Act requires drinking water to be free of any fecal coliform bacteria" (David Barry, EPA, Albuquerque Journal, July 31,2000)

Tables 3-4 and 3-5 do not reflect any adopted potable standards based on the Safe Drinking Water Act. This comparison of water quality standards points out that the standards of both the State of New Mexico and Pueblos do not indicate that naturally occurring potable water is expected to exist in the middle Rio Grande.

It follows that from the standpoint of the federal CWA, it is highly questionable that adopting intentional ingestion of raw river water is valid as an attainable use for the middle Rio Grande. Virtually all river sources for drinking purposes have water quality standards that apply to raw water before treatment, not as a raw water drinkable source. Given the documented environmental factors together with the many variable natural sources of microbial contamination, increasing human and animal populations and growing urban areas within watersheds, it is not a reasonable position to adopt water quality standards assuming attainability of raw potable waters by today's drinking water standards in most rivers, including the middle Rio Grande. In fact, this is generally the case around the world today. The Pueblos would be better served by changing their surface water quality standards to reflect what is safe, realistic, and attainable quality levels before conventional water treatments are applied.

3.2.6 City of Albuquerque Sewer Use and Wastewater Control Ordinance

To be compliant with the NPDES permit, The City of Albuquerque Sewer Use and Wastewater Control Ordinance (SUWCO) establishes requirements for users of the wastewater collection system. Discharge water is sampled and monitored for various inorganic compounds and elements, petroleum and animal-based oils, greases and other organics, temperature, and pH. Although microbes are not specifically monitored, hospitals, doctors' offices, and other generators of medical and biological waste must conform to disposal guidelines published by the EPA and the CDC (City of Albuquerque, 1996).

Discharge standards for wastewater are based on discharge volume and the potential for specific discharge contents to adversely affect the SWRP. The purpose of sampling and monitoring is to determine if wastewater pretreatment at the point of generation is effective and produces SWRP-safe discharge. Although the city's sewer and wastewater ordinance covers a wide range of chemical and biological pollutants, the regulations are generally not applied to discharge originating from residential properties (City of Albuquerque, 1996).

3.2.7 Animals on Noncommercial Properties

According to the City of Albuquerque Code of Ordinances the number and type of animals that may be kept on non-commercial properties depends on the size of the property and the type and number of animals housed there. In residential zones, there must be 10,000 square feet of open lot area for each cow or horse and 4,000 square feet for each sheep or goat. In residential zones the lot size must be at least 21,780 square feet, and must be fenced to prevent animals from grazing on adjoining properties (City of Albuquerque, Planning and Zoning Department).

According to the Valencia County Planning and Zoning Office, zoning ordinances that regulate the type and number of animals that may be housed on residential properties are lax, do not reflect community growth and are in the process of revision. Currently the zoning ordinances do not have requirements for waste retention (McCarthy, 2000).

3.2.8 Animals on Commercial Properties

Farm animals on commercial properties are regulated by the Concentrated Animal Feeding Operations 40 CFR 122 Appendix B and by 40 CFR 122.23. Concentrated animal feeding operations are defined by the length of time animals are housed on the property, the number and type of farm animals, and the actual or potential for discharge of animal waste into water (see Table 3-6).

Table 3-6: Concentrated Animal Feeding Operations (EPAb)

Type of Animal	Number Permitted for 45 Days or more over a 12-Month Period	Number Permitted if Waste-contaminated Runoff Discharges into Water
Slaughter or feeder cattle	1,000	300
Dairy cattle	700	200
Swine over 55 pounds	2,500	750
Horses	500	150
Sheep or Lambs	10,000	3,000
Turkeys	55,000	16,000
Laying Hens/Broilers if continuous flow watering system	100,000	30,000
Laying Hens/Broilers if liquid manure handling system	30,000	9,000
Ducks	5,000	1,500
Combination of steers, heifers, dairy cattle, swine over 55 pounds and sheep	1,000	300

3.2.9 Summary - Historical Findings

Information compiled from historical, regulatory, and other reports revealed the following potential impacts on Rio Grande river water quality:

- Wastes originating from birds, mammals, reptiles, and amphibians are a significant source of river microbial contamination

- LUSTs are a potential source of seepage and runoff to the river

- Old and malfunctioning septic tanks are a source of groundwater and some illegal surface water contamination to the river

- Historical data relating specifically to waterborne microbes (other than fecal coliforms, an indicator of water quality) in the Rio Grande is scanty or is lacking

- Point sources of direct discharge into the Rio Grande must routinely obtain a NPDES permit that is issued by EPA and emphasizes fecal coliforms as the classic indicator organisms for microbial contamination

- NPDES permit standards for discharge to the Rio Grande typically focus on the regulation of chemical pollutants

- In the City of Albuquerque, industrial discharges must meet City Ordinances or EPA categorical standards

- Zoning laws regulate the type and number of animals that may be kept on noncommercial properties

- Concentrated Animal Feeding Operations 40 CFR122 Appendix B and 40 CFR 122.23 regulate the type and number of animals that can be kept on commercial properties

- Concentrated animal feeding operation standards are more rigorous in locations where animal waste-contaminated runoff may discharge into surface water

3.3 Epidemiology

3.3.1 CDC Reportable Diseases: Incidents and Frequency

There are 52 "reportable diseases" where data collected by states is sent to the CDC and published in Morbidity and Mortality Weekly Reports (MMWR). The MMWR data compiled in Tables 3-7 and 3-8 is for waterborne diseases, where the reservoir for the infectious agent is water. Exposure to these infectious agents may also occur from ingestion, inhalation, or direct contact with contaminated food or water. The CDC data reported in MMWR does not discriminate between incidents of disease resulting from contact with contaminated drinking and/or contaminated recreational water or identify incidents of disease spread through the "oral-fecal route of transmission."

Table 3-7: Incidents of Reportable Potentially Waterborne Microbial Diseases – Cases 1998 and 1999 (USDHHS, CDCc)

Disease	United States 1998	Mountain Region 1998	New Mexico 1998	Nation 12/26/99	Mountain Region 12/26/99	New Mexico 12/26/99
Cryptosporidiosis	3,529	121	47	2,321	99	42
Hemorrhagic Diarrhea – *E. coli* 0157:H7	2,784	359	19	3,419	360	13
Legionellosis	1,204	69	2	943	49	1
Salmonellosis	39,406	2,402	280	37,752	3,035	368
Shigellosis	20,525	1,232	286	15,787	1,177	152
Hepatitis A	20,646	2,963	145	16,573	1,264	53

Table 3-8: Incidents of Reportable Potentially Waterborne Microbial Diseases – Cases as of June 2, 2000 (USDHHS, CDCd)

Disease	United States	Mountain Region	New Mexico
Cryptosporidiosis	438	34	2
Hemorrhagic Diarrhea – *E. coli* 0157:H7	627	57	2
Legionellosis	245	16	1
Salmonellosis	9,299	970	79
Shigellosis	5,409	386	41
Hepatitis A	4,248	369	38

New Mexico, when compared to the nation and the Mountain Region, has a low number of reported cases of potentially waterborne diseases. However, this does not take into consideration differences in population, reporting practices, or the myriad of social and economic factors that can affect disease reporting.

Incidents of reported disease is simply the number of reported cases. Although the reported number of cases does provide important epidemiological information, its analytical worth is improved when the frequency for disease per 100,000 people is calculated (see Table 3-9). The following estimated United States census population values (July 1, 1999) were used to calculate the frequency of certain potentially waterborne diseases (USCB, 1999):

- United States 274,013,256
- Mountain region 17,127,479
- New Mexico 1,739,844
- Bernalillo County 523,472

Table 3-9: Frequency per 100,000 People for Some CDC-Reported Potentially Waterborne Diseases – 1999

Disease Causing Agent	United States	Mountain Region	New Mexico
Cryptosporidium	8.4	2.0	2.4
E. coli 0157:H7	1.1	2.1	0.76
Legionella	0.34	0.28	0.058
Salmonella	13.8	17.8	21
Shigella	5.4	6.6	8.9
Hepatitis A	5.8	7.4	3.1

The frequency for many waterborne diseases is lower in New Mexico than it is in the Mountain Region or in the US. However, the frequency for illness due to *Salmonella* and *Shigella*, is higher in New Mexico than it is for other parts of the country.

3.3.2 New Mexico Public Health Reportable Diseases: Incidents and Frequency

Healthcare professionals are required to report incidence of certain diseases to the New Mexico Department of Health, some of which are not required to be reported to the CDC. The New Mexico Department of Health uses the information given in the patient's medical report to determine if exposure to recreational water may have been a cause for illness. Tables 3-10 and 3-11 tabulate potentially waterborne diseases for the years 1998 and 1999. The frequency of some locally reported and potentially waterborne diseases is tabulated in Table 3-12.

Table 3-10: Epidemiological Data Reported to the New Mexico Department of Health of Some Potentially Waterborne Diseases – Cases 1998 (Padilla, 2000)

		Recreational Water Risk				Recreational Water Risk		
Condition or Disease Causing Agent	**Cases Bern County**	**Yes**	**No**	**Not Known**	**Total Cases NM**	**Yes**	**No**	**Not Known**
Cryptosporidium	16	0	10	6	48	2	26	20
E. coli 0157:H7	6	0	5	1	19	3	13	3
Hepatitis A	34	No data	No data	No data	155	No data	No data	No data
Legionella	1	No data	No data	No data	2	No data	No data	No data
Shigella	79	4	51	24	305	13	104	188
Campylobacter	87	5	57	25	310	10	127	173
Amebiasis	8	1	2	5	11	1	2	8
Giardia	137	17	66	54	237	27	111	99
Totals	368	27	191	309	1087	56	383	491

Table 3-11: Epidemiological Data Reported to the New Mexico Department of Health of Some Potentially Waterborne Diseases – Cases 1999 (Padilla, 2000)

		Recreational Water Risk				Recreational Water Risk		
Condition or Disease-Causing Agent	**Cases Bern County**	**Yes**	**No**	**Not Known**	**Total Cases NM**	**Yes**	**No**	**Not Known**
Cryptosporidium	23	7	13	3	44	8	28	8
E. coli 0157:H7	5	0	5	0	13	1	9	3
Hepatitis A	7	No data	No data	No data	55	No data	No data	No data
Legionella	No data	No data	No data	No data	No data	No data	No data	No data
Shigella	31	2	17	12	156	6	58	92
Campylobacter	50	1	26	24	365	23	150	192
Amebiasis	1	0	0	1	7	0	0	7
Giardia	52	5	25	22	264	20	114	130
Totals	169	15	86	62	904	58	359	432

Table 3-12: Frequency per 100,000 People for Some Locally Reported and Potentially Waterborne Diseases – 1999

Disease Causing Agent	Bernalillo County	New Mexico
Cryptosporidium	4.4	1.4
E. coli 0157:H7	0.95	0.76
Hepatitis A	1.3	3.3
Legionella	None reported for 99	None reported for 99
Shigella	5.9	18
Campylobacter	16	18
Amebiasis	0.19	0.41
Giardia	9.9	15
Total Waterborne Diseases	32	53

Overall, the frequency for locally reported incidents of potentially waterborne disease tends to be lower in Bernalillo County than it is for the State of New Mexico (see Table 3-12).

3.3.3 Summary – Epidemiology

Epidemiological analysis of reported and potentially waterborne diseases reveals that:

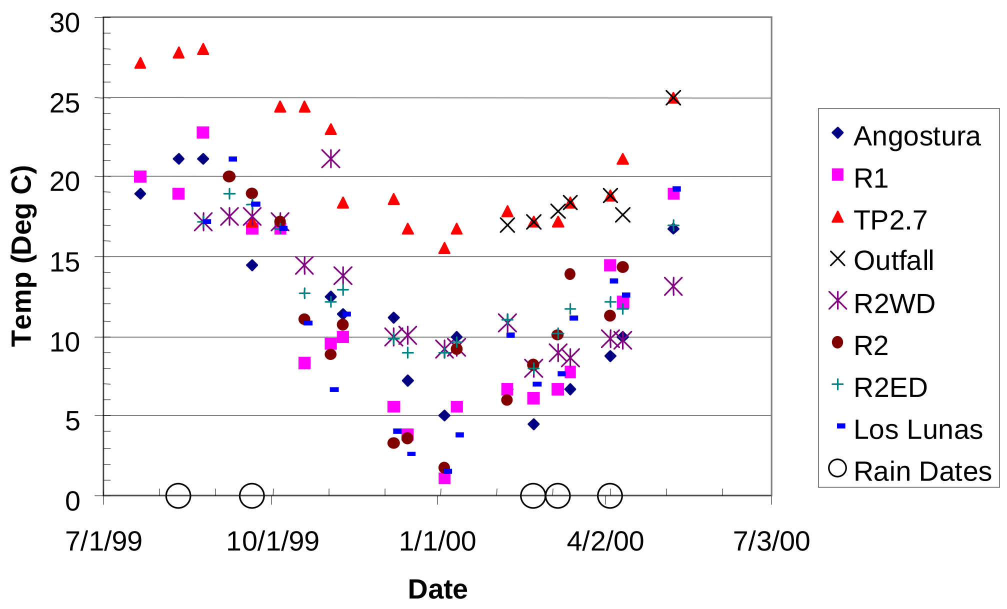
- There are incidents of potentially waterborne disease throughout the United States, in the State of New Mexico, and in Bernalillo County
- MMWR and CDC reports provide the means to nationally, regionally, and at the state level compare incidents and frequencies of reported potentially waterborne diseases
- Based on reported data, frequencies for Cryptosporidiosis, *E. coli* 0157:H7 hemmorrhagic diarrhea, Legionellosis, and hepatitis A are lower in New Mexico than in the United States
- Frequency for Salmonellosis and Shigellosis is higher in New Mexico than in the United States
- Frequency for reported potentially waterborne diseases in New Mexico is either lower or comparable to what is found in the other Mountain States
- Overall the frequency for locally reported potentially waterborne diseases is lower in Bernalillo County than it is for the State of New Mexico
- Locally reported incidents of potentially waterborne diseases do not always correspond to the number of cases reported to the CDC

3.4 Field Parameters

3.4.1 Temperature

The temperatures of composited water samples were measured in the field. SWRP-processed and Outflow water were consistently warmer than river or canal water. The temperatures of river and canal water, though cooler than discharge waters, reflect ambient temperatures. River and canal waters are colder during the fall and winter months and warmer in the spring and summer months. Figure 3.1 shows the water temperature at each of the sampling sites for each sampling event.

Figure 3-1: Water Temperature at Sampling Sites



3.4.2 River pH

The pH of composited water samples was measured in the field. The pH of SWRP discharge and Outflow waters were the closest to neutral. The pH at all other sites is more alkaline. The average pH of SWRP-processed water is close to 7 and the average pH of river and canal water ranged from 7.9 to 8.24. (See Table 3-13)

Table 3-13: River Water pH at Each of the Sampling Sites

Site	Angostura	R1	TP2.7	Outfall*	R2WD	R2	R2ED	Los Lunas
Average pH	7.90	8.04	7.21	7.03	7.77	7.91	8.24	7.90
Standard Deviation	0.64	0.74	0.50	0.15	0.68	0.71	0.61	0.66

*** Based on 7 measured values, all other site averages based on 24 measured values**

3.4.3 Rio Grande Flow

The USGS measures and records the flow of river water that passes a gaging station every 15 minutes. Historical data, published in the Water Resources Data New Mexico –Water Year 1997 (USGSb), was used as a comparative point of reference. The trend for 1999 shows a faster running river than what was measured during the 1996-1997 water year (see Table 3-14). The discharge rate from the SWRP is approximately 82.5 cubic feet per second (ft^3/s).

The Rio Grande flow rate also increases during traditional spring runoff and fall/winter Interstate Compact Water Rights Transfers.

Table 3-14: Provisional Discharge Rate from USGS Station 830000 (Beal, 1999 and Gold, 2000)

Date	Discharge ft^3/s[1]	Mean Discharge ft^3/s 1996-1997[2]
July 21, 1999	871	1049 (July 1997)
July 29	708	
August 11	3100	1026 (August 1997)
August 25	1700	
September 8	1170	1128 (September 1996)
September 21	1240	
October 6	701	338 (October 1996)
October 20	810	
November 3	911	597 (November 1996)
November 10	840	
December 8	855	674 (December 1996)
December 16	863	
January 5, 2000	943	
January 12	780	
February 9	887	
February 23	795	
March 7	758	
March 14	626	
April 5	587	
April 12	795	
May 10	951	
May 24	780	
June 7	1270	
June 13	1230	

[1]Gaging station 08330000, noon reading [2] Shown for comparison purposes only during sampling dates

3.4.4 Summary – Field Parameters

The regular assessment of Rio Grande temperature, pH, and discharge demonstrates that:

- SWRP processed discharge water is warmer than Rio Grande or canal water in winter months and the data shows this is a constant feature throughout the year

- The temperature of river or canal water fluctuates seasonally

- The pH of SWRP processed discharge water is close to neutral

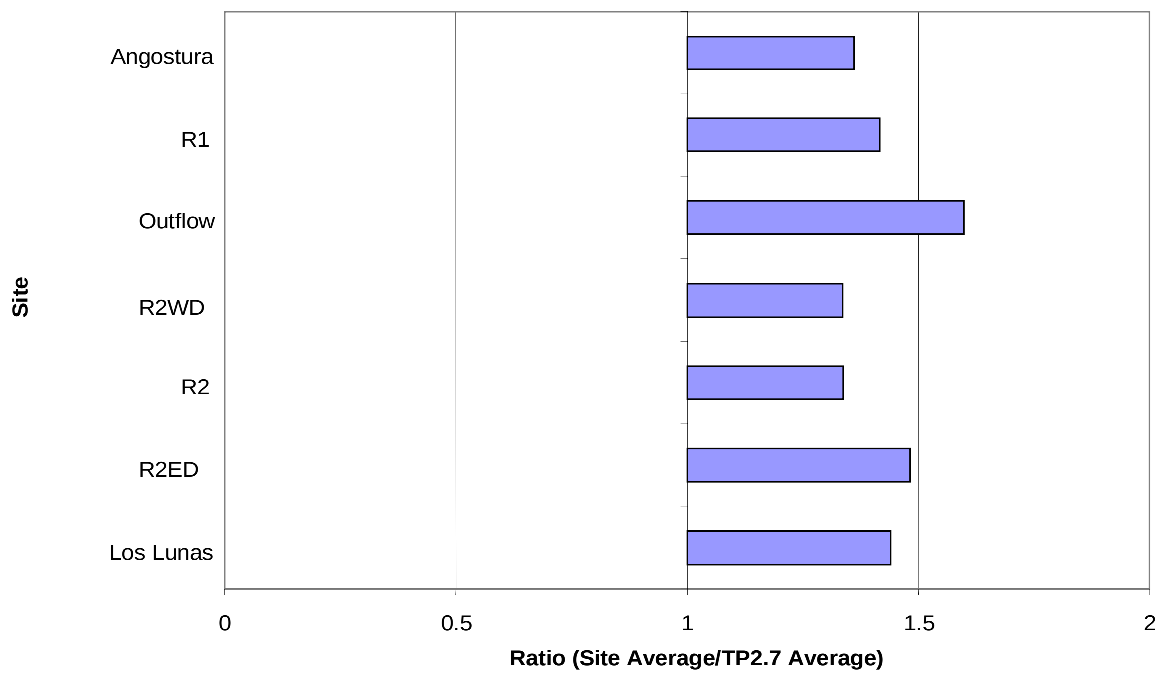
- The pH of river and canal water is somewhat alkaline
- The Rio Grande discharge flow rate tends to increase during traditional spring runoff, and fall/winter Interstate Compact Water Rights Transfers.

3.5 Laboratory Results

3.5.1 Lauryl Tryptose and MUG for Total Coliforms and *E. coli*

To evaluate LT with MUG results, in the context of the SWRP and river water quality, annual averages for total coliforms and *E. coli* were compared to the annual averaged values for total coliforms and *E. coli* at the TP2.7 – the SWRP discharge point. The ratio of the two values (site/TP2.7) is a comparative indicator of water quality. Figure 3-2 shows the ratio for total coliforms, and Figure 3-3 shows the ratio for *E. coli*.

Figure 3-2 Average Annual Total Coliforms (48 Hour) Ratio

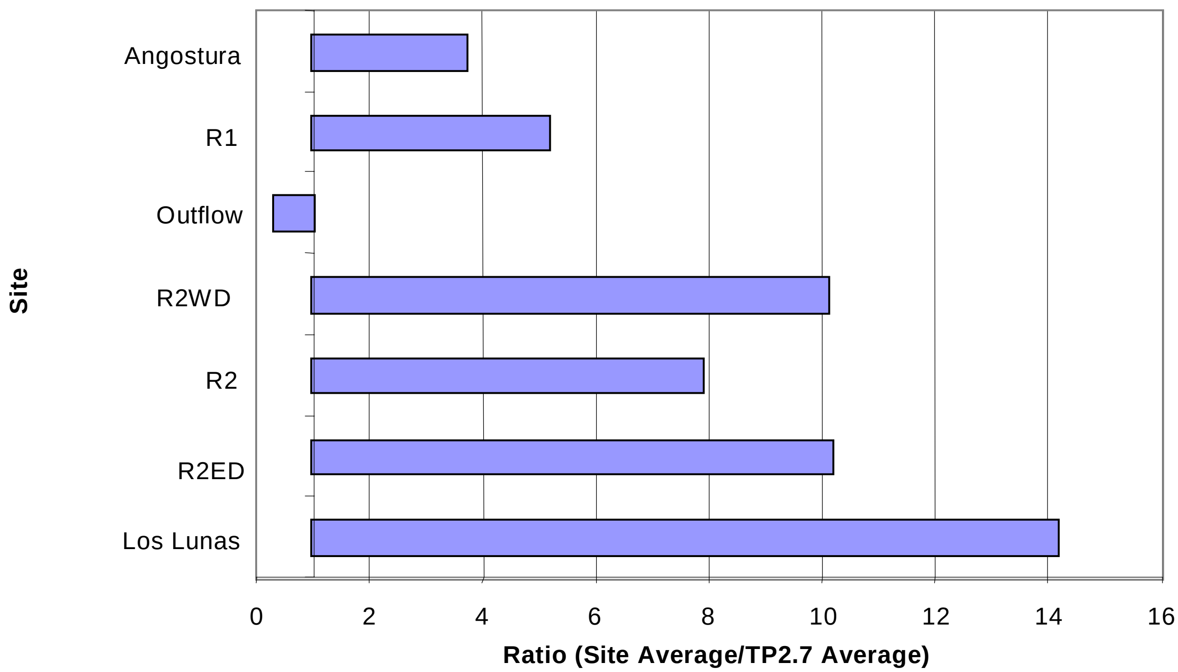


The comparison of total coliforms at TP2.7 to the total coliforms found at each of the other sites demonstrates that:

- Coliforms were consistently found at each of the sites
- TP2.7 had fewer total coliforms than all of the other sites

- On average, the Outflow had more coliform bacteria than TP2.7
- More total coliform bacteria were found at each of the other sites than were found at TP2.7
- With the exception of TP2.7 and the Outflow, total coliforms were fairly evenly distributed from Angostura to Los Lunas

Figure 3-3 Average Annual *E. coli* (48 Hour) Ratio



The comparison of *E. coli* at TP2.7 to each of the other sites demonstrates that:

- *E. coli* were consistently found from Angostura to Los Lunas
- TP2.7 and the Outflow had the lowest *E. coli* burdens
- On average there were fewer *E. coli* at the Outflow than at TP2.7 or the other river sites
- All other sites demonstrated the presence of more *E. coli* than either TP2.7 or the Outflow

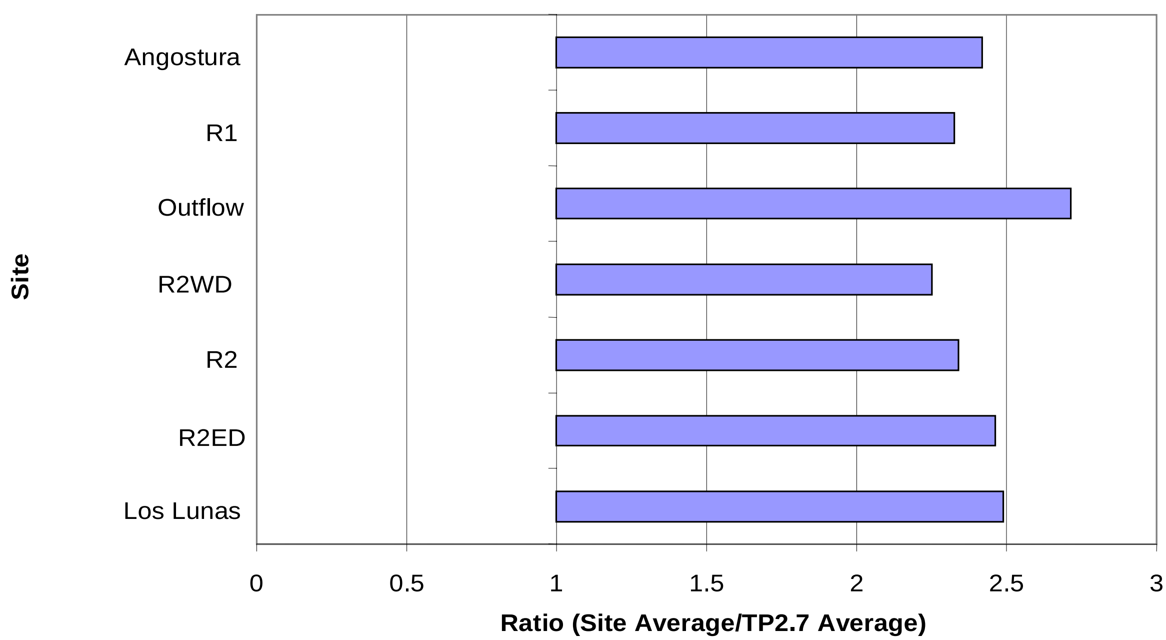
- There were more *E. coli* downstream of the SWRP than upstream from the SWRP

- Because downstream had lower levels of *E. coli* than the other sites, the source of *E. coli* was neither the SWRP nor the SWRP Outflow

3.5.2 PathoScreen for Hydrogen-Sulfide Producing Bacteria

Hydrogen-sulfide producing bacteria include various species of *Salmonella, Proteus, Klebsiella, Citrobacter, Clostridium* and *Edwardsiella*. These bacteria and other hydrogen-sulfide-producing bacteria are associated with fecal contamination and the presence of other coliforms. Figure 3-4 shows a comparison of the average annual hydrogen-sulfide producing bacteria to those found at TP2.7.

Figure 3-4 Average Annual Hydrogen Sulfide Producing Bacteria Ratio



The comparison of hydrogen-sulfide producing bacteria at TP2.7 to the hydrogen-sulfide producing bacteria found at each of the other sites demonstrates that:

- Hydrogen-sulfide producing bacteria were found throughout the surveyed area

- TP2.7 had the lowest measured levels of hydrogen-sulfide producing bacteria

- All of the other sites demonstrated more hydrogen-sulfide producing bacteria than TP2.7

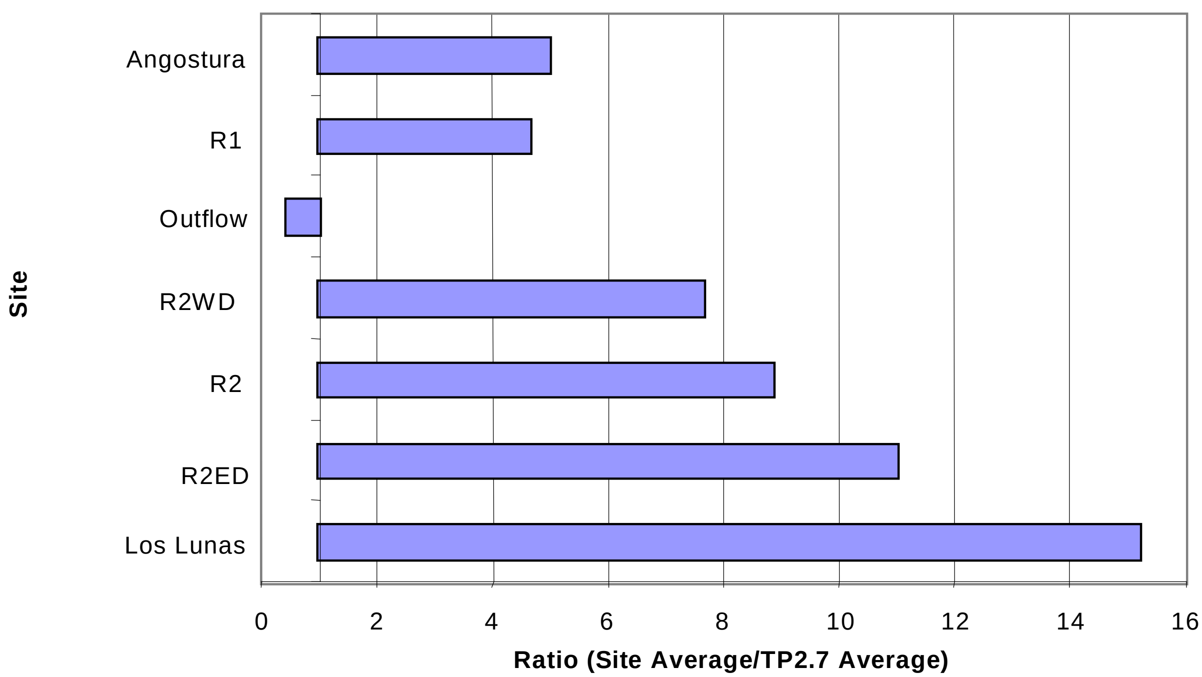
- The Outflow had the highest levels of hydrogen-sulfide producing bacteria

- All other sites were similarly affected by hydrogen sulfide producing bacteria

3.5.3 Confirmed Test for Fecal Streptococci

The fecal streptococcal group consists of a number of bacterial species associated with the feces of warm-blooded animals. Because specific fecal streptococci are associated with the fecal matter of certain animals, it is possible, although not practical, to determine the origin of fecal contamination through complicated DNA and RNA typing (CDM, 2000). Therefore, DNA and RNA typing was not performed as part of this study. Figure 3-5 shows a comparison of fecal streptococci at TP2.7 to the other sites.

Figure 3-5 Average Annual Fecal Streptococcus Ratio



The comparison of fecal streptococci at TP2.7 to the fecal streptococci found at each of the other sites demonstrates that:

- Fecal streptococci were present throughout the sampled area:
- Both TP2.7 and the Outflow had less fecal streptococcal bacteria than sites samples upstream or downstream from the SWRP
- On average the SWRP Outflow had fewer fecal streptococci than TP2.7
- On average there were fewer fecal streptococci bacteria at sites upstream from the SWRP than were found downstream.

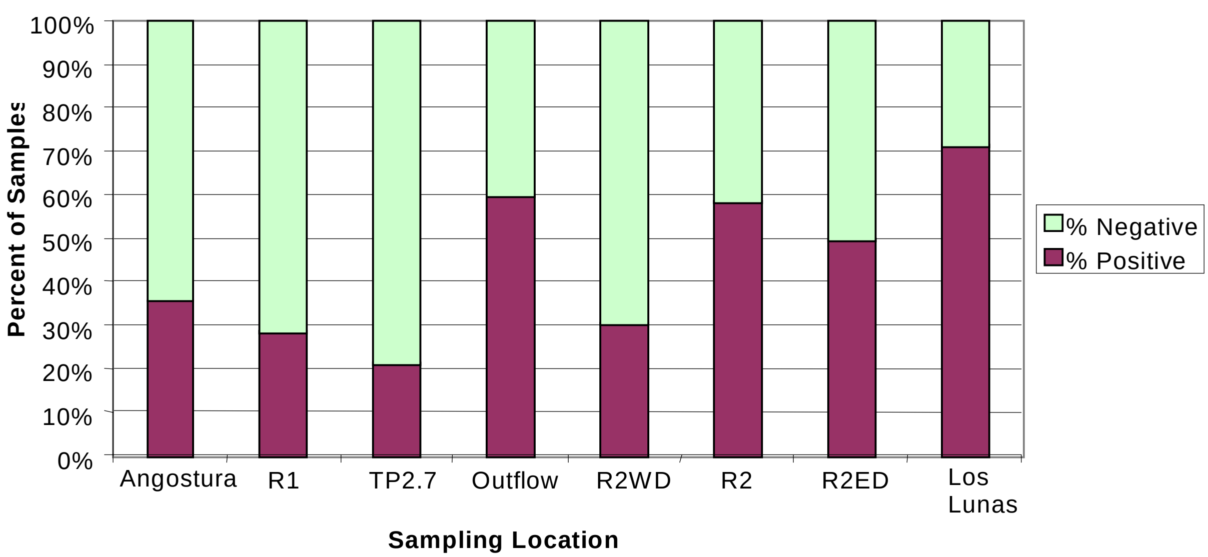
- The SWRP was not the source for downstream fecal streptococci bacteria
- Los Lunas had the most fecal streptococci

3.5.4 Assessment for *E. coli* 0157: H7

E. coli 0157:H7 is a newly emergent food and waterborne pathogenic strain of *E. coli*. Because there is no standard confirmed test for this organism, *E. coli* 0157:H7 positive samples should be considered as "presumptive" positive. Figure 3-6 shows the percent of samples testing positive or negative for *E. coli* 0157:H7.

Approximately 60% of samples tested positive at the Outflow, compared to just over 20% of samples at TP2.7. The Outflow sampling location was only sampled 10 times during the course of the study, while the other sites were sampled 24 times.

Figure 3-6 Percent of Samples testing positive or negative for *E. coli 0157:H7*



General observations concerning the presumed presence of *E. coli* 0157:H7 in water samples collected from each of the sites follows.

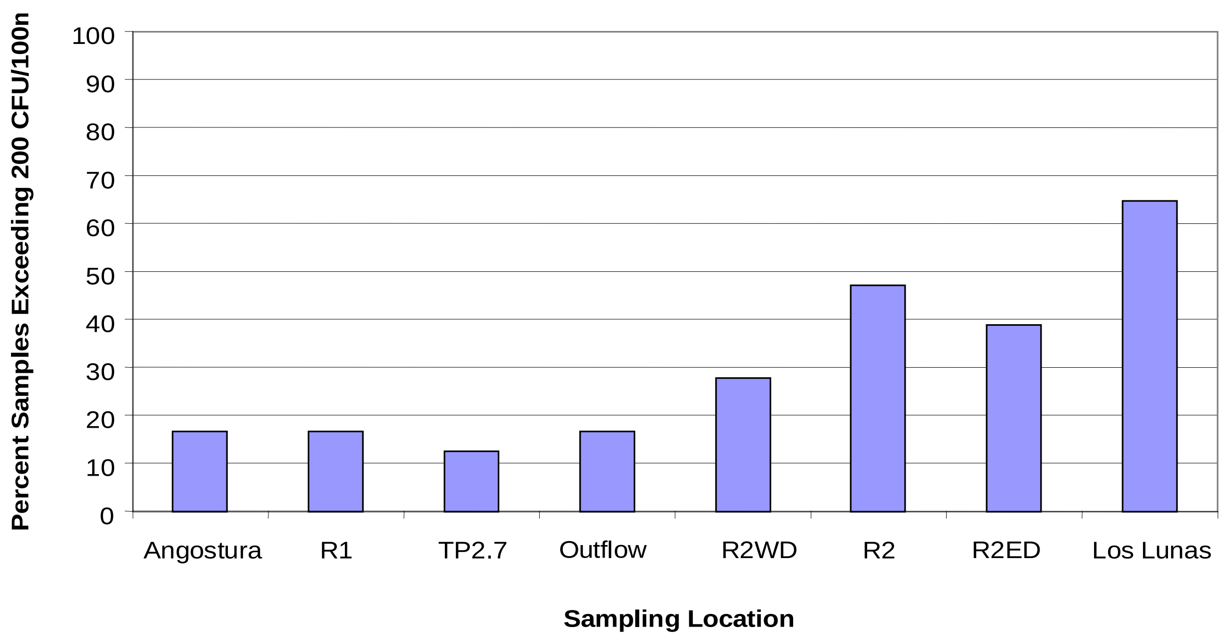
- Organisms that by many criteria appear to be *E. coli* 0157:H7 were present at each of the testing sites.
- Slightly more than twenty percent of the TP2.7 samples tested presumptive positive for *E. coli* 0157:H7

- All other sites demonstrated more positive testing events than TP2.7
- There tended to be a higher percentage of positive testing events downstream from the SWRP than upstream
- Los Lunas had the greatest percentage of positive testing events
- TP2.7 was not the source of downstream *E. coli* 0157:H7

3.5.5 Rio Grande and SWRP Water Quality Assessment - Fecal Coliforms

Fecal coliforms are the bacterial standard used to assess water quality. Unlike the total coliform group of bacteria, these organisms grow at 45 degrees Celsius. Therefore it is possible to use temperature as a means to differentiate between total and fecal coliform populations. Although *E. coli* grows under both conditions, the elevated temperature selects for those bacteria able to survive the elevated temperatures encountered in the gut of warm-blooded animals. The NPDES permit for the SWRP gives a value of 200 CFU / 100 ml as the allowable instantaneous maximum level for fecal coliforms. Figure 3-7 shows the percent of fecal coliform membrane filter samples exceeding 200 CFU / 100 ml at each of the sampling sites.

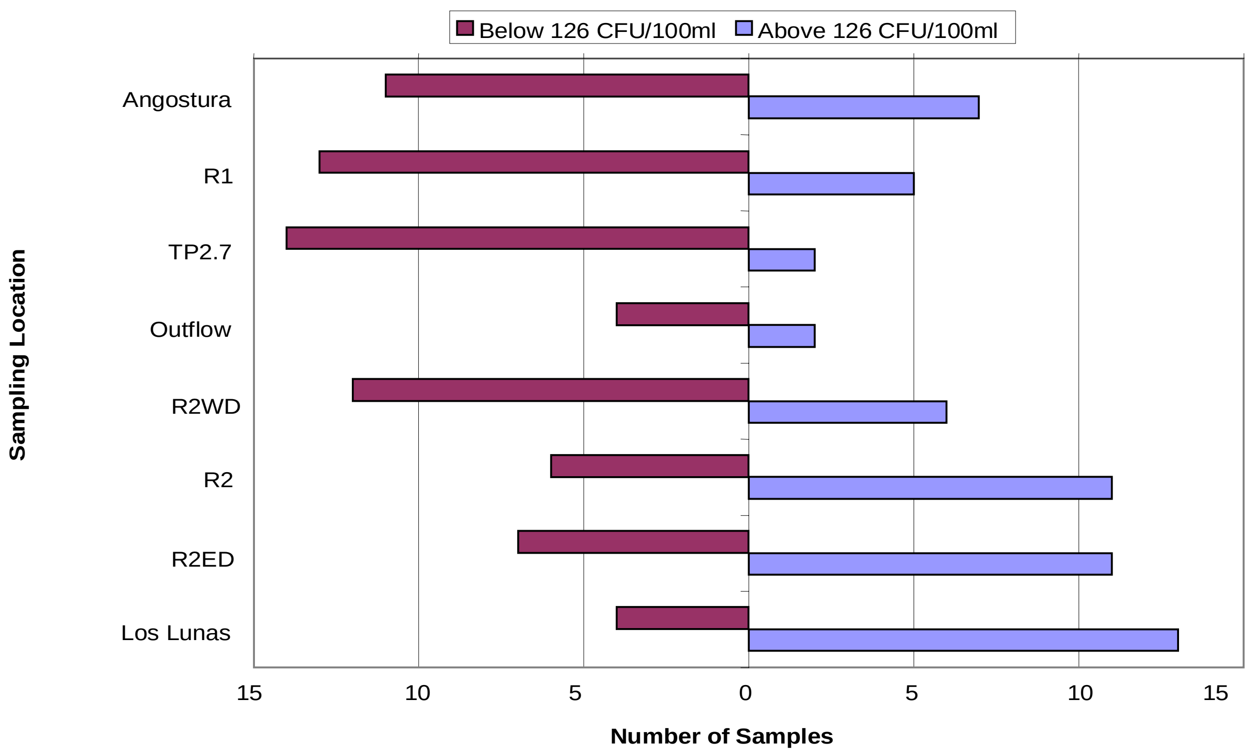
Figure 3-7 Percent Fecal Coliform Membrane Filters Samples Over 200 (Instantaneous Maximum)



Evaluation of Rio Grande and SWRP water using the fecal coliform instantaneous maximum of 200 CFU / 100 ml from the NPDES permit reveals that:

- Incidents of fecal coliforms above the instantaneous maximum level did occur at all sampling sites, including TP2.7
- TP2.7 had the fewest incidents of exceeding the instantaneous 200 CFU / 100 ml maximum
- Los Lunas had the most incidents of exceeding the instantaneous 200 CFU / 100 ml maximum
- Exceedence of the 200 CFU / 100 ml maximum tended to occur more frequently downstream from the SWRP than upstream from the SWRP
- The SWRP was not a significant source for fecal coliforms

Figure 3-8 Fecal Coliform Membrane Filters



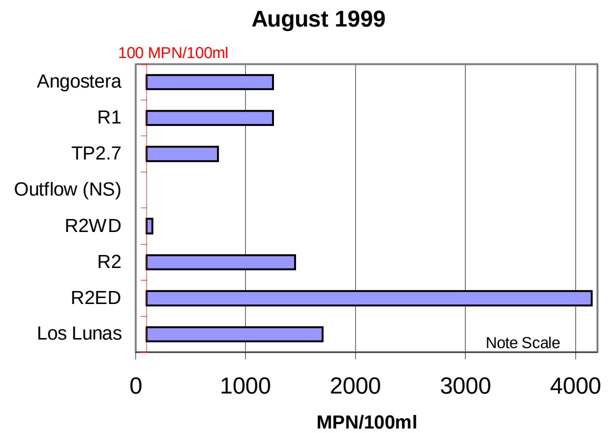
Evaluation of Rio Grande and SWRP water using the 126 CFU / 100 ml standard for the protection of human health as outlined in the USEPA "Ambient Water Quality Criteria for Bacteria" (Figure 3-8) revealed that:

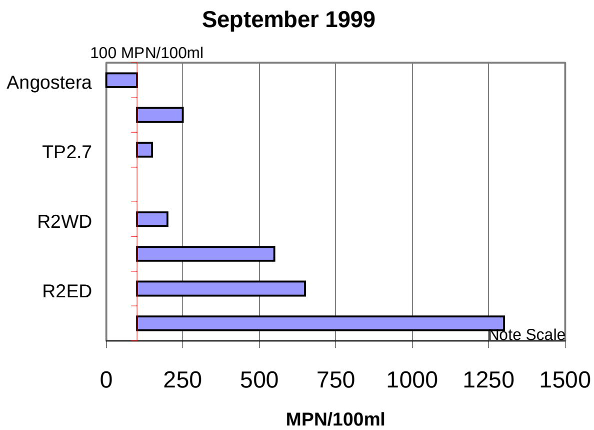
- TP2.7 and the Outflow had the fewest incidents exceeding 126 CFU / 100 ml criteria for the protection of human health (Outflow was sampled 10 times versus 24 times for TP2.7)
- Sites downstream from the SWRP had the most incidents exceeding the 126 CFU / 100 ml criteria for the protection of human health

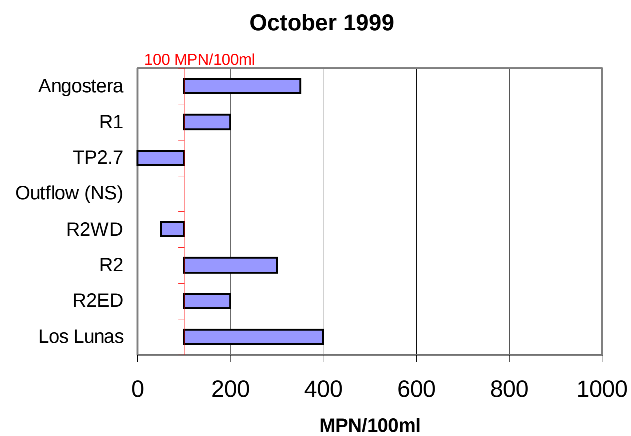
- The SWRP and the Outflow to the river were not significant sources of downstream fecal coliforms.

Figure 3-9, on the following 3 pages, shows the 30-day average level of fecal coliforms at each of the sites.

Figure 3-9 Fecal Coliform Membrane Filters Deviation From 30-Day Average Standard







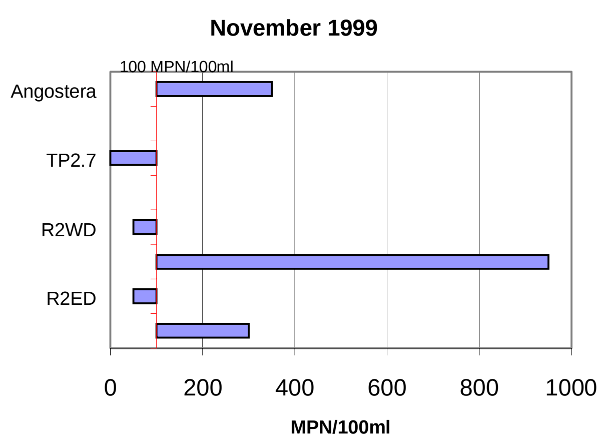


Figure 3-9 Fecal Coliform Membrane Filters Deviation From 30-Day Average Standard

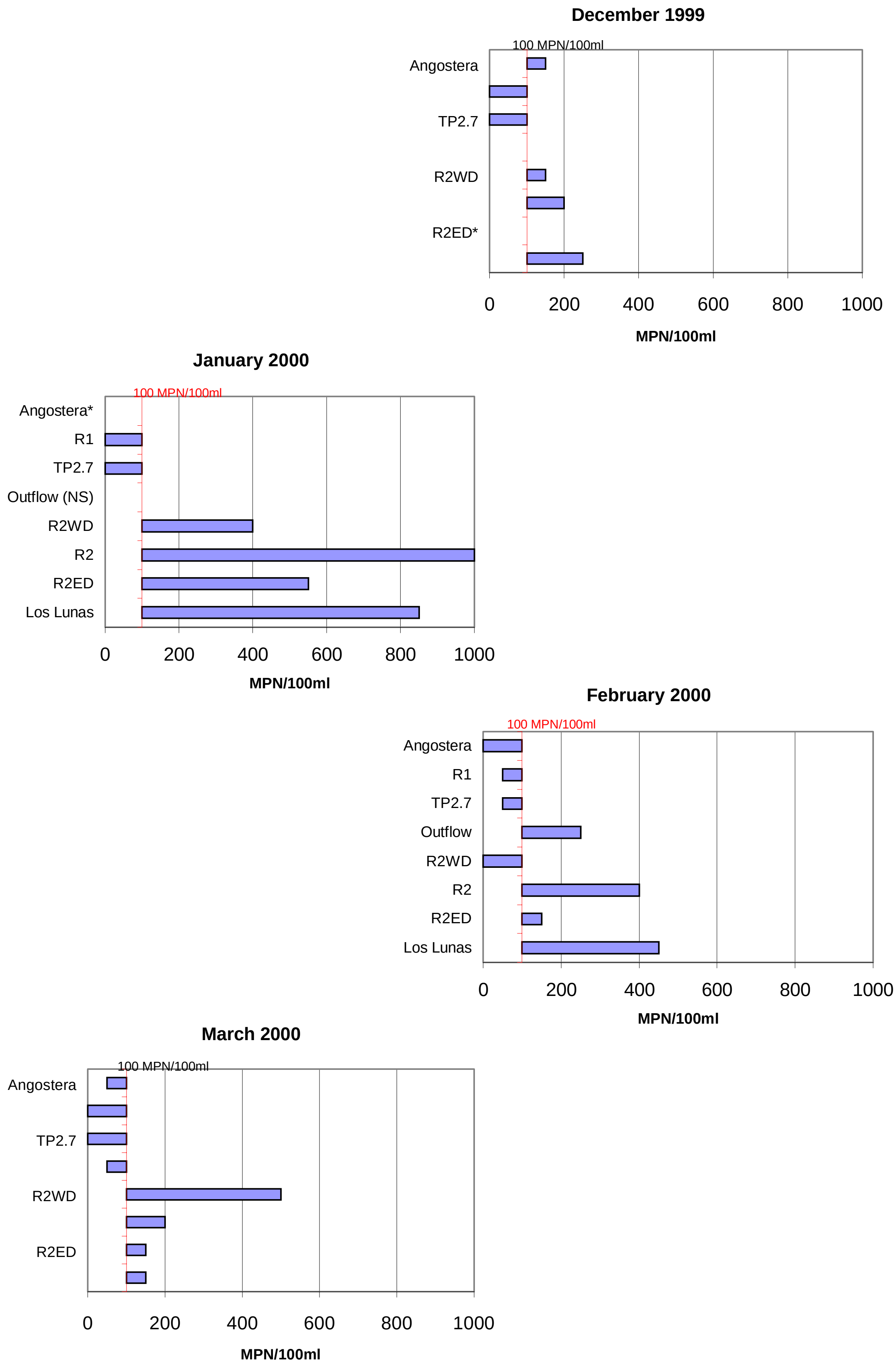
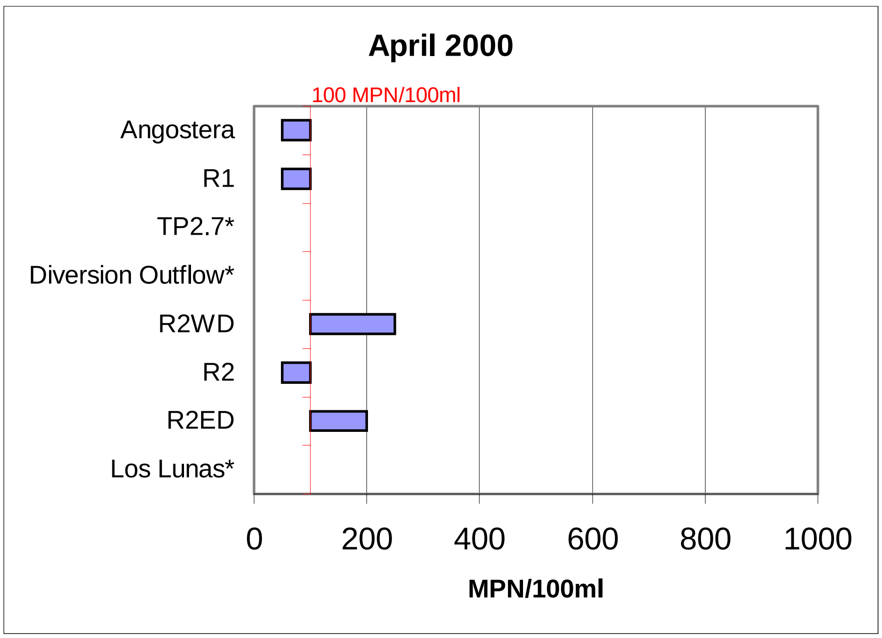


Figure 3-9 Fecal Coliform Membrane Filters Deviation From 30-Day Average Standard



Evaluation of Rio Grande and SWRP water using 100 CFU / 100 ml 30-day average standard reveals that between August 1999 and April 2000:

- TP2.7 and the Outflow had the fewest incidents of exceeding the 100 CFU / 100 ml 30-day average
- Sites downstream of the SWRP had the most incidents of exceeding the 100 CFU / 100 ml 30-day standard
- SWRP and the Outflow to the river were not significant sources of fecal coliforms

3.5.6 Summary of Laboratory Results

- Total coliforms, *E. coli*, hydrogen-sulfide producing bacteria, fecal streptococci, and *E. coli* 0157:H7 were isolated at all sites between Angostura and Los Lunas
- Sites north of the SWRP Outflow tended to have lower microbial burdens than sites south of the SWRP Outflow
- Total coliforms and hydrogen sulfide producing bacteria were found in similar concentrations between Angostura and Los Lunas, with the exception of TP2.7 which had less than the other sites
- By all laboratory based criteria, the TP2.7 site demonstrated a lower microbial burden than the sites north and south of the SWRP
- By all laboratory-based criteria R2ED, R2WD, R2, and Los Lunas were the sites that were most heavily impacted by potentially waterborne bacteria
- By many criteria the Outflow was less impacted than the southern sites, but carried a heavier microbial burden than TP2.7 or sites north of the SWRP
- The SWRP and the Outflow were not significant source of the microbes encountered at the downstream sites
- The source(s) of potentially waterborne microbes appeared to be downstream of the Outflow

There appears to be some unique sources of microbial contamination downstream of the SWRP Outflow

Photo 3-1: Isleta Pueblo Golf Course

Photo 3-2: Aerial view of Rio Grande and the Bosque

Photo 3-3: Angler in the SWRP Outfall Channel

Photo 3-4: Concentrated Animal Feeding Lot

Photo 3-5: Enclosed animals near irrigation canals

Photo 3-6: Scrap yard along Rio Grande drains

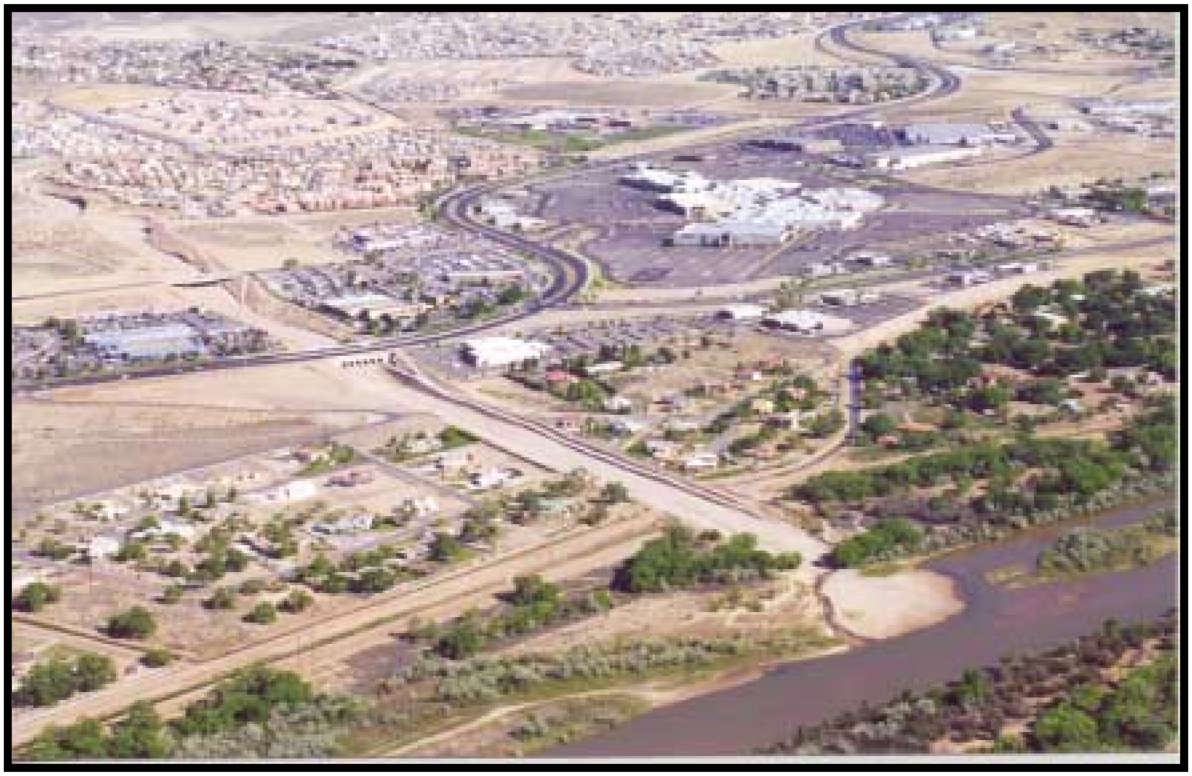


Photo 3-7: Cottonwood Mall

Photo 3-8: Expansion of residential areas along Rio Grande

Photo 3-9: Sandhill cranes along the Rio Grande, Bosque del Apache

Photo 3-10: Leaking Underground Storage Tanks removed and stored at industrial site along the Rio Grande

Photo 3-11: Preparation of water samples

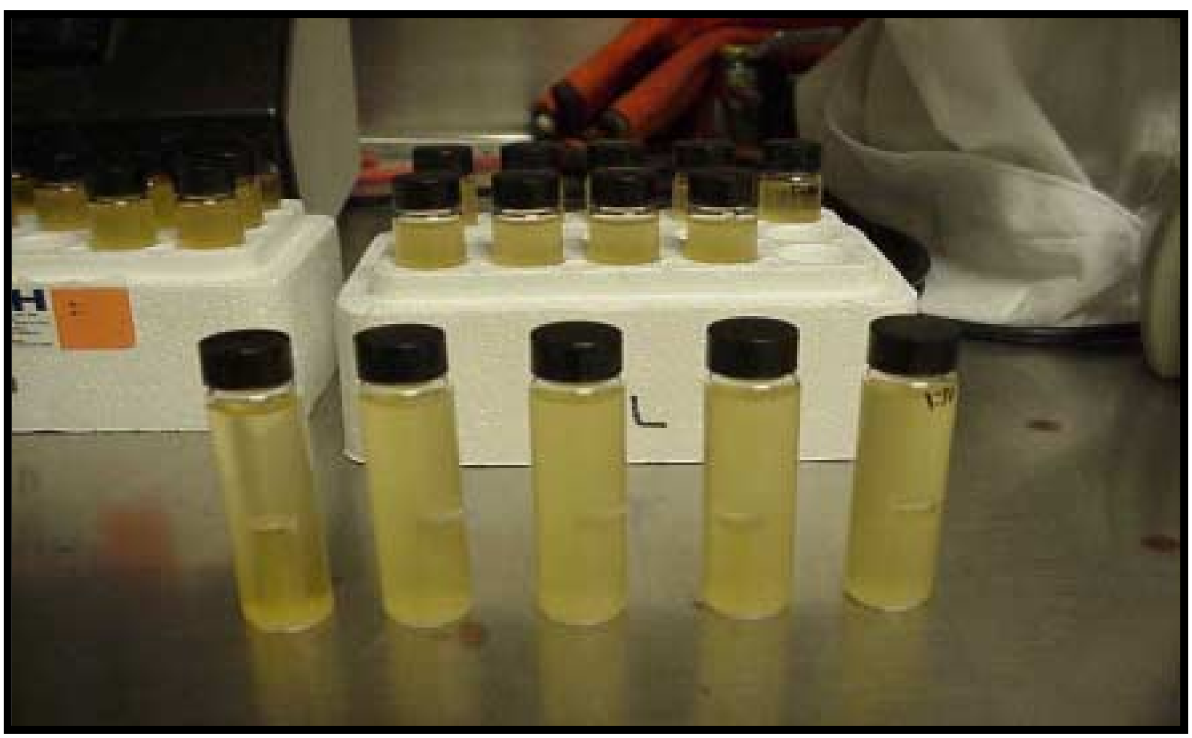


Photo 3-12: Bacteria testing of water samples

Section Four

Section 4
Discussion

4.1 Site Reconnaissance

The site reconnaissance provided an overview for both the unique and regular features of the middle Rio Grande area and made it possible to observe seasonal variations which may affect runoff and seepage to the river. Site visits in conjunction with the walk-through and the fly-over gave the "big picture" view of the environmental features that may affect Rio Grande water quality (Photo 4-1).

Viewing Rio Grande environs from the ground provided specific examples of point and non-point sources of runoff that may affect water quality. The aerial view afforded the opportunity to see the physical connections between poor land-use management practices and potential sources of runoff and seepage to the river (Photo 4-2). From the air, breaches in and interconnections between the riparian zone, large impervious surfaces, and other runoff and seepage-producing conditions are easily observed.

The overall field-based impression is that non-point sources of runoff and seepage between the Angostura and Los Lunas sampling sites are the major contributors to Rio Grande water quality impairment. While many of these non-point sources of runoff and seepage are intimately related to the local geography, climate, and soil characteristics, others are associated with human activity in a rapidly growing high-desert community. They include:

- Compacted soil, impermeable surfaces, arid climate
- Sparse vegetation, breaks in riparian border, erratic rainfall
- High density housing, landscaping, water use
- Animals on residential properties, animal waste management, intensive agriculture, flood irrigation
- Animal waste management on commercial properties, high animal density
- Intermingling of urban and rural lifestyles
- High density industrialization, business centers, and golf courses

Runoff and seepage originating from the above, intertwined with non-point sources contribute silt, microbes, and chemical nutrients to the Rio Grande. In addition, when water runs over impervious surfaces (roads, rooftops, parking lots, and sidewalks) water is heated. Thermal pollution increases solubility of chemical pollutants, decreases oxygen solubility, and encourages the growth of anaerobic and potentially pathogenic bacteria. The effect of warmed water entering streams and rivers is well documented and is called "thermal shock" (Johnson, 1995).

Geologic erosion occurs with or without human influence. However, human activities such as construction, animal management practices, and agriculture accelerate the rate of erosion and the deposition of silt and nutrients into water.

Silt, which is made up of suspended soil particles, attracts and binds nutrients, pollutants, and microbes. Therefore silt promotes chemical recalcitrance and microbial perseverance in erosion and runoff-affected water.

4.2 Historical Assessments

The review of historical documents reveals that the following gaps in federal and local regulations affect Rio Grande water quality:

- Federal and local regulations do not apply to residential generators of point and non-point sources of runoff and seepage

- Local zoning ordinances that apply to domestic animals on residential properties are not enforced

- The number of animals that may be kept on commercial properties after "Concentrated Animal Feeding Operations" and BMP regulations are applied is inappropriate for the conditions encountered in the middle Rio Grande region

- Local land-use and zoning ordinances do not assure or encourage regular septic tank maintenance

As is evident from surveys conducted by the USDA, the State of New Mexico, and the Audubon Society as well as from the walk-through observations, wild and domestic animals living near or in the Rio Grande are a major source of microbial contamination to the river. Although it is neither practical nor realistic to control bird migration through the Rio Grande corridor, considerable progress can be made if runoff and seepage, originating from domestic animal waste, are prevented from entering the Rio Grande.

City zoning ordinances regulate the type and number of animals that can be kept on residential properties. However, based on walk-through observations (Photo 4-3), it appears these ordinances are not rigorously enforced. Although City ordinances are not applicable to Bernalillo County or the adjoining Sandoval or Valencia Counties, problems associated with large numbers of animals kept on these out-lying residential properties also contribute to runoff and seepage to the Rio Grande.

There is a tremendous gap between local zoning laws (4 cows per 10,000 square feet) and the number of animals that may be kept on a Concentrated Animal Feeding Operation where waste is discharged into water (200 dairy cattle or 300 feeder cattle).

Although these concentrated feedlot values may be appropriate in other parts of the country, they are not applicable the to conditions encountered in the middle Rio Grande valley.

The regulatory gap between residential and commercial property also extends to waste stream management and its contribution to runoff and seepage to the Rio Grande. Septic tanks, no longer a practical method to treat residential liquid waste, are a documented contributor the Nation's water contamination problem. However, unlike automobile owners, homeowners are not required to give proof of septic tank maintenance and performance.

The residential usage of pesticides and fertilizers, a significant source of nutrient-rich runoff and seepage, encourages the proliferation of waterborne microbes. However, unlike their commercial counter-parts, homeowners neither receive training about the use and handling of these products nor are they subjected to permitting and monitoring requirements.

In addition to residential use of fertilizers and pesticides, golf courses are a documented source of fertilizer and pesticide-rich runoff (Photo 4-4). Two golf courses, one overlooking the Rio Grande near Angostura and the other overlooking the Rio Grande near the I-25 bridge (R2), are potential sources of runoff to the river. However, because both of these golf courses are on Indian Pueblo land, local and federal runoff and containment regulations are not applicable.

Various USGS and State of New Mexico reports provide detailed information concerning chemical pollution and the physical parameters that may affect river water quality. However there is very little information in these documents that is pertinent to microbial assessment and Rio Grande water quality. Fortunately, because of NPDES permitting requirements, the Albuquerque Public Works Department has on record monitoring results for fecal coliforms at several sites upstream and downstream from the SWRP. Although the data provides some insight concerning the prevalence of fecal coliforms, nothing is known about the prevalence and persistence of other relevant waterborne pathogens.

Both the EPA and the American Society for Microbiology (ASM) have stated in recent publications that risks for microbial contamination have been largely ignored because of the regulatory emphasis on the control of chemical pollutants (ASM, Office of Public Affairs and USEPA Region 6). They state that because of changing patterns in water use, aging water treatment systems and outdated risk assessment protocols, this situation poses a significant threat to the public's health. To remedy this situation both the ASM and the EPA recommend a more integrated and coordinated approach between the various government agencies involved in water protection as well as a national microbial assessment of United States water.

4.3 Epidemiology

Data collected and reported to the New Mexico Department of Health and the CDC demonstrates a low incidence and a low frequency for potentially waterborne diseases in Bernalillo County and in the State of New Mexico. Relatively few of these reported incidents are linked to known exposures to recreational water, which in addition to the Rio Grande, includes lakes as well as private and public swimming pools.

Although epidemiological data helps to identify trends and changes in disease patterns, it is difficult to compare data received from different states or from different reporting agencies. The reporting of medical data reflects and is influenced by many complex social, economic and medical parameters that include:

- Perception of illness - sick enough to go to a doctor
- Having access to medical care
- Receiving treatment based on laboratory results rather than empirical treatment
- Coordination between local and national reporting of certain diseases
- Caregiver compliance with local and national reporting expectations

Overall the frequency for potentially waterborne diseases in New Mexico and Bernalillo County is similar or lower than what is observed elsewhere. The only exception is a slightly higher frequency of infection by *Salmonella* or *Shigella*. However, both of these bacteria are more closely associated with foodborne, rather than waterborne, disease. Intrinsic and extrinsic issues that make it impossible to evaluate the significance of this finding include:

- Differences in reporting
- Perception of illness
- Access to medical care
- Regional and local food preferences
- Regional and local methods used to prepare foods
- Poverty and personal hygiene habits

The data also demonstrates a lower frequency in Bernalillo County for certain locally reported diseases that what is seen in the State of New Mexico. Again there are many intrinsic and extrinsic issues that make it impossible to evaluate the significance of this finding that include:

- Rural and isolated life-style outside of Bernalillo County
- Higher dependence on well water outside of Bernalillo County
- Poverty
- Less available information about water protection, personal hygiene and the transmission of disease
- Rural areas less likely to have community wastewater treatment facilities
- Proportionally more people working and living in close contact with animals and animal waste
- Proportionally more people working and living in close contact with contaminated ground and surface water

4.4 Field-Based Parameters

Temperature, pH, and flow rate are three abiotic, or non-biological, measures that are used to assess chemical and physical characteristics of the Rio Grande environment. Although changes in river temperature, pH, and flow rate are not usually the result of biological phenomena, they influence the type and number of microbes that can grow in the river.

The temperature of the composited sample was measured in the field. Although this helps to characterize the sample it is not a true reflection of river conditions. The temperature of Rio Grande water reflects local and seasonal weather conditions as well as the conditions encountered at each testing site. Samples taken from the Rio Grande ranged from a low of 4 degrees Celsius (January 2000) to a high of 23 degrees Celsius (June 2000). However, the temperature of SWRP-discharge samples was warm throughout the year. The low for TP2.7 was 16 degrees Celsius (January 2000) and the high for TP2.7 and the Outflow was 26 degrees Celsius (June 2000). Elevated temperatures are a result of incoming domestic wastewater to the SWRP. However, once discharged, the water quickly adjusts to ambient conditions. The water temperatures measured downstream from the SWRP were consistent with the temperatures recorded at the other river sites.

Water temperature affects the solubility of nutrients and selects for the growth of certain microbes. Because oxygen is less soluble in warm water its concentration can influence the balance between aerobic and anaerobic bacteria. The potentially waterborne pathogens tend to be anaerobes, so low dissolved oxygen would tend to support their growth.

The relative alkalinity and acidity (pH) of Rio Grande water samples, a reflection of the local geology, affect the solubility of available nutrients and chemical contaminants. Due to geologically recent volcanic activity the natural water has a high mineral content and tends to be alkaline. Although far from a simple relationship, the effects of pH and available nutrients synergistically interact to support the growth of specific types of microbes.

Over the year the pH of river samples has ranged from a low of 6.8 to a high of 9.0 pH units. On the average the pH of all river samples was 7.9 pH units. During the same time period the pH of processed discharge was, with rare and insignificant exceptions, 7.1 pH units.

River flow is regularly monitored by USGS gaging stations along the Rio Grande. The recorded flow rate is influenced by local weather, weather upstream from the gaging station, flow contributed by point and non-point runoff and is regulated by upstream dams.

River flow affects oxygenation through turbulence and mixing as well as by the modulation of water volume on temperature. The Rio Grande water volume influences the concentration of contaminants and nutrients and therefore affects the growth and support of microbial populations.

Rio Grande flows, recorded between July 21, 1999 and June 13, 2000 (USGS gaging station 08330000) ranges from 3100 ft^3/s on August 3rd to 587 ft^3/s on April 5th. It is interesting to note that both of these measurements were taken within 36 hours of rain. On a daily basis, the SWRP discharges approximately 55 million gallons of treated wastewater to the Rio Grande. This value corresponds to a flow rate of 82.5 ft^3/s.

It is difficult to make a correlation between river flow and the number and types of microbes isolated at the various testing sites. Rio Grande discharge, though influenced by other bodies of water, weather, and runoff is artificially controlled. However, as it has been documented in other studies, one would expect to find a correlation between runoff and microbial contamination (Crane et al., 1983 and Tiedmann et al., 1987).

4.5 Laboratory-Based Assessments

Bacteria and other microbes are ubiquitous throughout the environment. Therefore their presence in SWRP discharge and river water is expected. The least specific of the microbial assessments used in the river study is the LT48 test for total coliforms. This bacterial designation includes all rod-shaped, Gram negative bacteria capable of producing gas and acid from lactose while incubated at 35 degrees Celsius. Although used to indicate the presence of gut-derived bacteria, these criteria also include many non-fecal bacteria that are normally found in soil and water.

Total coliforms are found throughout the Rio Grande testing area. Water collected from TP2.7 tends to have a lower burden for total coliforms than all of the other sites.

This is not unexpected as this water is disinfected with chlorine that is removed prior to discharge to the river.

Just outside TP2.7 at the Outflow, the number of total coliforms increases. This finding is a reflection of the large numbers of birds, fish, and reptiles that live in and near the Outflow as well as inclusion of total coliforms associated with the soil and suspended silt.

The MUG test is a measure of the number of *E. coli*. These bacteria, part of the normal gut flora, indicate the presence of fecal organisms in water. Both TP2.7 and the Outflow have a lower burden for *E. coli* than all of the other sites up and downstream from the SWRP.

E. coli 0157:H7 is a recently identified *E. coli* strain that can cause hemorrhagic diarrhea and on occasion death. The bacterium, part of the normal flora of cows and other animals, is transmitted to humans in contaminated food and water. Not much is known about the presence and persistence of *E. coli* 0157:H7 in surface water.

Using a media that selects for *E. coli* and differentiates between different strains of *E. coli*, it was possible to isolate and presumptively identify the presence of *E. coli* 0157:H7 in water samples collected from each of the sites. Sites up and downstream from the SWRP demonstrated more presumptive positive events than TP2.7 and the Outflow. The farm animal waste and runoff from properties along the river is the likely source of this bacterium.

Fecal coliforms is another sub-grouping within the total coliform designation. These bacteria, the current New Mexico indicator organism for fecal contamination, are grown at 44.5 degrees Celsius, a temperature that selects for gut-derived coliforms and selects against the growth of environmental coliforms.

Enumeration of fecal coliforms demonstrates that TP2.7 has the fewest incidents of exceeding the instantaneous 200 CFU / 100 ml maximum limit and the 100 CFU / 100 ml 30-day average outlined in the City's NPDES permit. Similar fecal coliform criteria for water safety were also frequently achieved at the Outflow to the river. The greatest exceedences of the above criteria were downstream near the Isleta Pueblo downstream to Los Lunas. The Los Lunas sampling location had the highest number of samples that exceeded 200 CFU / 100 ml. The 126 CFU / 100 ml recommended criteria for the protection of human health (EPA 2000) was greatly exceeded at locations upstream and downstream of the SWRP. The SWRP effluent had the lowest number of samples that exceeded the 126 CFU / 100 ml criteria.

Hydrogen-sulfide producing bacteria are a measure of non-coliform bacteria. This group of bacteria includes many of the gut-derived potentially waterborne pathogens. Both TP2.7 and the Outflow have a lower burden for hydrogen-sulfide producing bacteria than river sites up and downstream from the SWRP. The Outflow tends to have a heavier burden for these organisms that TP2.7. This is not an unexpected result as birds, fish, and reptiles, well-documented reservoirs for hydrogen-sulfide-producing *Salmonella*, live near and in the Outflow waters.

The fecal streptococci are a group of bacteria associated with the feces of warm-blooded animals. Although these organisms were found at all testing sites, TP2.7 and the Outflow demonstrated the lowest fecal streptococcal burdens. Sites downstream from the SWRP are more heavily impacted than upstream sites. Although testing sites downstream from the SWRP tended to be adversely impacted by fecal streptococci, the source of these bacteria does not appear to be from the SWRP.

4.6 Historical, Field and Laboratory Results in a Community Context

In a recent article in the Albuquerque Journal (April 6, 2000), New Mexico is identified as one of several states that has failed to address water pollution caused by runoff from farms and contaminated rainwater. This published statement supports the findings in this study that non-point sources are contributing to water quality impairment, particularly with regard to potential pathogens.

Throughout the study area there are many examples of inappropriate land-use practices that contribute contaminated runoff and seepage to the Rio Grande. It appears that local zoning ordinances, used to control the type and number of animals housed on residential properties, are not enforced.

Low compliance with local zoning ordinances may reflect a lack of public education. Although many citizens undoubtedly feel that what they do on their own property is their own business, they may be unaware of the far-reaching affects of animal, landscaping, and agricultural runoff on the environment.

There are many commercial properties (Photo 4-5) located near the Rio Grande that demonstrate inadequate waste containment measures. The runoff and seepage from these properties contributes nutrients and assorted microbes to the river. In the larger context of urban encroachment, residential and commercial development contributes to the impairment of the Rio Grande by replacing water-permeable soil with impermeable surfaces.

Finding potentially pathogenic organisms in surface water does not necessarily mean there will be incident of waterborne disease in the community. As discussed earlier, the transmission of waterborne disease within communities is more commonly due to poor hygiene practices and the cross-contamination of food. The pathogen may have originated from a local water supply or it may have been “imported” in foods or by people who carry it in their intestines. Recent progress in genetic engineering makes it possible to determine if an outbreak of waterborne disease is due to local or imported organisms.

Potentially waterborne diseases are reported to the New Mexico Department of Health in Santa Fe and to the Centers for Disease Control in Atlanta, Georgia. The majority of these nationally and locally reported incidents are due to infection by *Shigella*, *Salmonella*, *Giardia*, hepatitis A and in some parts of the country *Cryptosporidium*. These microbes, though likely to be found in local surface waters, are usually linked to the consumption of contaminated food or to exposures in daycare centers, summer camps, or nursing homes. New Mexico has experienced some water-linked cases of cryptosporidiosis, however the majority of cases were not linked to surface water as the probable source of infection.

Analysis of potentially waterborne disease data for the Mountain States, New Mexico, and Bernalillo Country demonstrates that the incidence and frequency of disease in the middle Rio Grande communities is similar to or lower than that is found elsewhere. This indicates that despite the presence of potentially waterborne pathogens in Rio Grande water, there is a low frequency of these diseases in the community.

Both historical and recent laboratory data demonstrate the presence of fecal coliforms upstream and downstream from the SWRP. Though there have been a few isolated incidences where there have been slight exceedences of the fecal coliform limit in the City's NPDES permit, the water discharged to the river usually has fewer fecal coliforms than the water upstream or downstream from the SWRP.

In addition to fecal coliforms, the laboratory-based portion of the study assessed the SWRP and several upstream and downstream sites for other potential waterborne pathogens. These results also demonstrate that even for these unregulated and potentially pathogenic bacteria, SWRP and Outflow water is of better quality than upstream or downstream water.

Although the contributions of wild birds and animals can not be discounted, it is runoff and seepage from commercial and residential properties as well as the encroachment of the river communities that have the biggest influence on distribution and prevalence of potentially waterborne pathogens in the Rio Grande. North or upstream from the SWRP the following are potential sources of microbially-contaminated runoff and seepage to the Rio Grande:

- Domestic animals, wildlife, and waterfowl
- Septic tanks
- Runoff from the Santa Ana golf course, agriculture and flood irrigation practices, residential landscaping, commercial properties, and stormwater point sources.
- Industry
- New high-density neighborhoods

South or downstream from the SWRP the following are potential sources of microbially-contaminated runoff and Seepage to the Rio Grande:

- Domestic animals, wildlife and waterfowl
- Septic tanks
- Industry and manufacturing
- Metal recycling yards
- Runoff from Isleta Pueblo golf course, agriculture and flood irrigation practices, residential landscaping
- Older high-density neighborhoods
- Growth of semi-rural “bedroom” communities

4.7 Recent (July 2000) Domestic Wastewater Discharge to the Rio Grande

As reported in the Albuquerque Journal during July 2000 (see Appendix B), the City of Rio Rancho (Photo 4-6), located upstream from the City of Albuquerque, experienced numerous exceedences of permitted levels of fecal coliform for the past several years. A major discharge estimated at 400,000 gallons of settled sludge occurred due to equipment failure on July 13, 2000 (see Appendix B).

Both the City of Rio Rancho and the State of New Mexico performed sampling upstream and downstream of the spill. Of note is that upstream sampling detected higher than expected counts of fecal coliform, causing the NMED to extend their advisory notice cautioning against swimming, etc. in the river. The NMED was quoted as saying “the river has by its natural course fecal coliform bacteria in the water, and we acknowledge it is dirty” (Tito Madrid, Albuquerque Journal, July 31, 2000). NMED also stated that no reasons were known for the river’s continuing contamination.

This points to the facts that many factors are at play in relation to the microbial populations found in the middle Rio Grande and that they are generally poorly understood.

Photo 4-1: Aerial view of the middle Rio Grande

Photo 4-2: Sources of runoff to the Rio Grande

Photo 4-3: Goat and sheep rearing in residential area along Rio Grande

Photo 4-4: Algae blooms from nutrient-rich runoff

Photo 4-5: Inadequate waste containment along Rio Grande

Photo 4-6: Rio Ranch Wastewater Treatment Plant

Section Five

Section 5
Conclusions

This study demonstrates that Rio Grande water quality issues are complex and involve many interlaced community and environmental parameters. There are many natural contributory microbial sources impacting Rio Grande water quality. Human regulation and use of Rio Grande waters for beneficial purposes have led to a closing circle of direct impacts on microbial conditions in the river. Although some of these factors are difficult or impossible to control, some can be achieved through public education, by enforcement of current zoning laws, and by implementing BMP to control non-point sources of microbial pollution. Coordination and cooperation among public and private parties and agencies at federal, state, local, and tribal levels will be necessary to effect meaningful changes.

Indicator Species

It is clear that microbial indicator species such as fecal coliform, although useful, are not a true indication of potentially human pathogenic microbial contamination. A better indicator organism such as *E. coli* should, as is recommended by EPA, be considered for adoption to more accurately indicate potentially human sources of microbial pollution.

Ambient Water Quality Standards

Microbial water quality standards for the middle Rio Grande vary in both spatial and political dimensions. The State of New Mexico's standards vary from those adopted by the Sandia and Isleta Pueblos on the same waters. Only the Isleta and Sandia Pueblos have microbial standards for ceremonial intentional raw water ingestion but none of the Pueblo standards are based on actual potable Safe Drinking Water Act levels. It is doubtful that intentional ingestion of raw river water is a valid designated or attainable use under the federal Clean Water Act.   More appropriate standards could be developed for the middle Rio Grande as a treatable water source as opposed to a drinkable raw source of water.

Permit Limits

Permit limits for municipal water reclamation facilities place higher standards on treated discharges than exist for the river itself. The City's microbial limits are 10 times more stringent than for the Rio Grande receiving waters. Compared to the river, municipal facilities must sample and monitor discharges regularly. In reality, the natural microbial conditions of the Rio Grande vary widely and exceed established standards quite often. Sampling for the Albuquerque SWRP as required by permit is not representative and should be modified to become so. An averaging method, per EPA recommendations, should apply.

Downstream Trend of Higher Microbial Pollution

Microbial concentrations generally increase downstream in this reach of the Rio Grande. The highest concentration increases were found starting at the far southern end of the sample locations i.e. generally at and below the Isleta Pueblo boundaries. It is generally not known how much shallow ground water and riverside canals in the river reach through and south of Isleta Pueblo impact the river. It is known that over time there have been efforts to curtail ground water pollution in those areas in the middle Rio Grande. LUSTs located by GIS near impacted groundwater sites also exist in the reach and may be contributing factors. Land use practices are also likely candidates as contributing to surface water contamination that reach the river and canals.

Other findings for this study are:

- Rio Grande microbial water quality is apparently adversely affected by both point and non-point sources both upstream and downstream of the City's wastewater treatment plant. Examples follow:

  a) Significant numbers of wild birds that use the Rio Grande as a major flyway as well as resident animal populations, together adversely affect the microbial quality of the river all year.

  b) Livestock rearing and livestock operations produce contaminated runoff, which can and does enter the canals and river.

  c) Land use and land management practices contribute contaminated runoff and seepage into the canals and river.

- Microbial water quality upstream from the SWRP is less impaired than sites downstream from the SWRP, for mostly unknown reasons at this time.

- Microbial water quality upstream and downstream of the City's discharge is significantly more impaired than discharges coming from the SWRP and outflow channel.

- Water being discharged to the Rio Grande from riverside drains and canals is of lower quality than that being discharged from the SWRP.

In summary, efforts to reduce non-point source loading to the river have the potential to improve water quality in the middle Rio Grande. Land use practices e.g. animal/livestock holding areas adjacent to the river and canals could be improved to prevent direct microbial contamination. Groundwater influences may be significantly contributing to river and canal microbial populations, and deserve further research. Factors affecting groundwater (septic tanks, livestock practices, leaking underground tanks) appear to deserve attention equal to surface non-point sources of pollution.

Strict regulatory requirements placed on municipal discharges to the middle Rio Grande routinely require close monitoring and achievement of lower microbial concentrations, as much as 10 times more stringent, than allowed for the river itself. Municipal water reclamation facilities serve to safeguard the river and have, over time, greatly improved water quality in the river.

Pathogen impairment of water quality in the middle Rio Grande will likely continue to be a problem until both groundwater and non-point sources of pollution are addressed. What is difficult to estimate is the degree to which long lasting microbial improvement in water quality is achievable given the diversity of both man-made and natural factors that are responsible.

The Next Steps

Through the efforts of this study, many of the complex parameters that influence Rio Grande water quality have been identified. Although many of the environmental issues are not easily controlled or modified – other issues, relating directly to human activity can be modified through public education and the promulgation of scientifically sound and attainable environmental regulatory standards.

In this study, non-point sources of nutrient and microbe-contaminated runoff to the Rio Grande have been implicated as having the greatest influence on the River's water quality. The State of New Mexico recently published a Request for Proposal (RFP) to address the problem of non-point sources of pollution to the State's waterbodies (RFP, FY01 Section 319(h) Grants, Surface Water Quality Bureau, NMED). The State of New Mexico has listed several areas for study, implementation or demonstration that fulfill the goals and objectives as stated in the "New Mexico Non-point Source Management Program", December 1999. These areas of study, all directly relevant to the middle Rio Grande and long-term goals to improve river water quality include:

- Implementation / demonstration of BMP
- Post-burn rehabilitation
- Prevention of catastrophic wildfires
- Reduction of erosion and sedimentation from rural roads, agricultural practices, etc.
- Projects with an emphasis on riparian buffers
- Improved awareness and / or management of urban runoff
- Information / education of engineers and and / or developers concerning BMPs
- Improvements in livestock management

- Projects that restore floodplain function
- Restoration of natural stream channel morphology and,
- Streambank stabilization

In addition to these important areas of study, the consideration of the following topics are also considered relevant for meaningful water quality improvements:

- Establishment of programs to improve public understanding of their role in protecting the State's waterbodies
- Programs to monitor changes and improvements in water quality as affected by the implementation of BMPs for non-point source runoff
- Encourage cooperation between local, state, federal and tribal agencies to address common water quality concerns
- Encourage the promulgation of scientifically sound, consistent and attainable environmental regulatory standards

Section Six

Section 6
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Appendices

Appendix A

Appendix B